EFFECT OF WINDSPEED TO WAVE HEIGHT ON CONTINENTAL SHELF MALAYSIA

By

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16395

Dissertation submitted in partial fulfilment of

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CERTIFICATION OF APPROVAL

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Approved by,

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(Prof. Ir. Dr. Mohd Shahir Liew)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

JANUARY 2016

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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SHARIFAH NUR AINIZA BINTI KHAIDZI

ABSTRACT

Correlation between wind speed and wave height need to take into consideration when designing offshore platform in order to optimize the usage of the platform material and optimize the operational period. In this study, the wave characteristic effected by wind generation is determined by using descriptive statistics analysis. The result of the correlation were then being analysis to know the sea development state in Continental Shelf Malaysia by comparing ratio of significant wave height with respect to the corresponding wind speed with each calculated significant wave height from P-M Spectrum Model, JONSWAP Spectrum and NALL Spectrum. The MetOcean Data recorded at three (3) operating regions located in Malaysian waters which are Peninsular Malaysian Operation, Sarawak operation and Sabah Operation were used in order to make a realistic descriptive correlation between wind speed and wave height. The finding were also compared between seasonal monsoons and non-seasonal monsoon to make a comparable analysis of the different between the monsoons on the Continental Shelf Malaysia. From the analyzes results, calculated significant wave height form NALL Spectrum Model and JONSWAP Spectrum Model shows lowest ratio with respect to the ratio of SEAFINE MetOcean data.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Geographically, South China Sea which involved six countries; Brunei, China, Malaysia, Philippines, Taiwan and Vietnam are located at the arm of the western Pacific Ocean which borders the Southeast Asian mainland. In addition, South China Sea is bounded on the northeast by the Taiwan Strait; on the southeast and south by Borneo, on the east by Taiwan and the Philippines, the east coast of the Malay Peninsula; on the west and north by Asian mainland, and the southern limit of the Gulf of Thailand. As defined in Article 122 of the UN Convention on the International Law of the Sea (UNCLOS) [15], South China Sea is a semi-enclosed sea that exposed to a seasonal ocean circulation predominantly controlled by the seasonal monsoon season with driven South China Sea wave and wind circulation; these seasonal monsoon are named as Northeast Monsoon (NE) and Southwest Monsoon (SE). Technically, the northeast (NE) winds prevail from November to March and southeast (SE) winds prevail from April to September over the South China Sea. These monsoon were classified due to the predominant wind direction is from the northeast and the southwest respectively.

As site of one on the globes most contentious, South China Sea could physically be classified as Fully Developed Sea or Partially Developed Sea as its own status development status. By knowing the sea development status, it would be very helpful and useful when designing the offshore design structure. In further elaborate to this understanding, while knowing the sea development status (for example, fully development sea), it will give benefit to engineer in order to make useful of the type of structure to be used to optimized the lifespan of offshore structure. On the other explanation, it would be easier to predict the possible safety issues to be considered during operations in order to mitigate the possibility of oil rig incident to happen. Numerous studies have been conducted related to these parameter especially wind and waves. In term of knowing the status of sea development, there are only several studies have been conducted such as correlation study of wind and wave parameter in order to know the relationship between those parameter. Since wave are mostly generated by wind, thus it is important to know the correlation between those parameter in order to know the sea development status specifically for South China Sea itself.

Wind-waves are the most important parameters to be considered as compared to others parameter involved such as air temperature, frequency and current conditions that affecting offshore structures design, maritime structures and other marine and coastal activities. The majority of ocean waves are wind generated in which wind generated wave in the generation area. However, by looking out at the sea, one could never sees a constant progression of identical waves besides the sea surface is composed of waves of varying heights and periods moving in different directions.. With these irregular and non-constant irregular with respect to their direction, amplitude and frequency, wind wave were considered as a very complex natures. Thus, the shape and the condition of sea surface in the presence of wind waves cannot be deterministically described. However, there are two approaches for describing the irregular nature of wind waves. One of them is to use the statistical probability distributions of individual wave characteristics. The other way is to use the wave energy spectrum.

Basically, there were numerous studies have been conducted involved the study of wind waves parameter such as Grow Reanalysis of Ocean Wave (GROW) project, West Africa Normals and Extremes (WANE) hindcast study and Dutch Offshore Wind Energy Converter (DOWEC) project. In Malaysia, several studies have been conducted that related to wind waves parameter. For this study, wind wave data from hindcast Meteorological and Oceanographic (MetOcean) are used to illustrate the study in details. Generally, MetOcean study was introduced in world wide to study the atmosphere and an interdisciplinary science studying of the ocean and coasts respectively. This study involved the statistical properties of SEAFINE MetOcean data collection including several parameters such as wind speed, wave height, wind and wave direction, tidal effects and many more. These data were collected in the basins of the coast of Malaysia located at selected offshore location; Peninsular Malaysia Operation (PMO), Sarawak Operation (SKO) and Sabah Operation (SBO) respectively. The collected wind speed and wind direction data were basically recorded using interconnected anemometer installed at the platform and placed 10m above sea level.

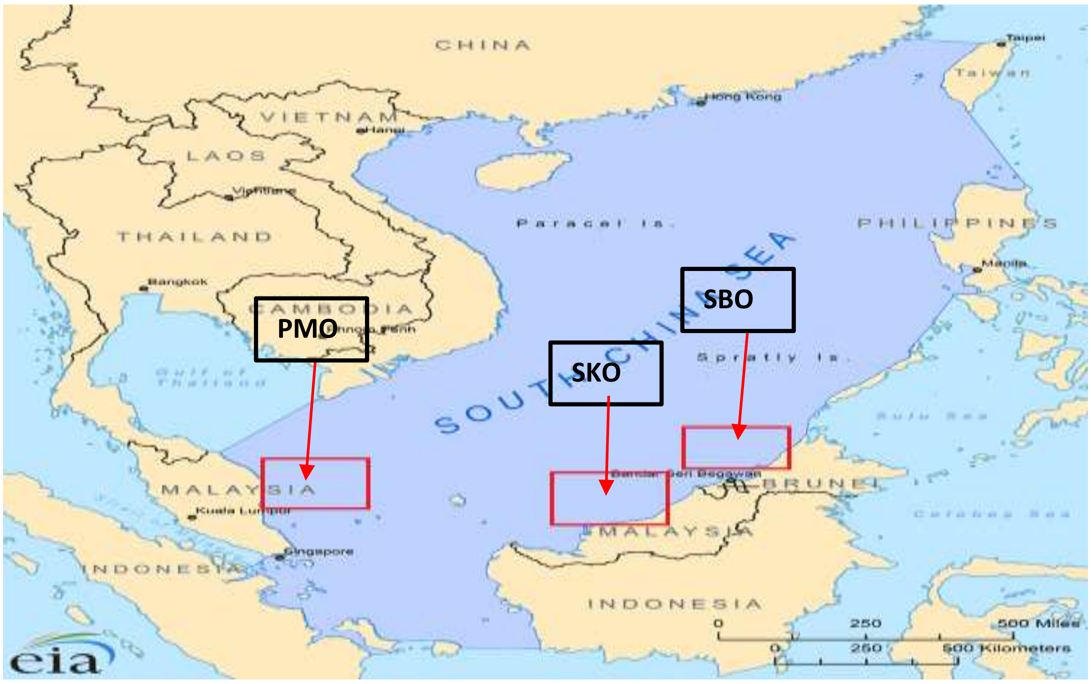


Figure 1.0: Location of PMO, SKO and SBO

1.2 PROBLEM STATEMENT

1.2.1 Absence of local correlation wind and wave parameter study

Recently wind waves have been widely recognized as main key element that controls the air-sea interaction, because wind waves represent the sea surface state or roughness. The sea surface wind is the most fundamental element in order to know the sea development.

Knowing that correlation wind and wave parameter shows a significant impact on the design and operability of fixed and floating offshore platforms. However, the existing correlation study between wind and wave parameter are developed in different regions such as in Chesapeake Bay, Virginia USA [1]. Thus, this has created a need on developing a local correlation wind and wave using regional parameter recorded at Malay basins.

1.2.2 Absence of Sea states study of Malay basins

Various studies have been done involved the development of wind, wave and current hindcast. This studies also conducted based on joint industry project (JIP) such as Grow Reanalysis of Ocean Wave (GROW) project, BORE (Beaufort Sea, USA), BOMOS (offshore Brazil) and CASMOS (Caspian Sea) [5]. All this kind of studies are generally to validate the SEAFINE MetOcean data. Besides, most of the JIP studies such as In the Dutch Offshore Wind Energy Converter (DOWEC) project, the development of these parameter were basically to determine MetOcean design parameters [5].

Moreover, the determination of sea states also important to help offshore design criteria, operational planning and marine operations. This is because fully and partially developed sea are involving different criteria which possibly will effect the design of offshore platform. Therefore, this raises the need for developing and identifying the correlation of wind and wave parameter especially in Malay basins.

1.3 PROJECT OBJECTIVES

As referring to the research project, the objective of this research are literally formulated:

1. To study the wave characteristic in Malay basins.
2. To develop a realistic correlation between wind and wave parameter in Malay basins.
3. To investigate dominant seasonal monsoon for PMO, SKO and SBO regions by using wind rose method.
4. To study sea development of Malay basins.

1.4 SCOPE OF STUDY

1. To extract and analyze the wind and wave MetOcean data according to seasonal monsoon through Matlab Software.
2. To plot wind rose using wind speed from MetOcean data respectively in order to investigate the dominant wind direction.
3. To define and calculate the frequency and wave energy spectrum using PM Spectrum for fully developed sea, JONSWAP Spectrum, and NALL Spectrum for partially developed sea.
4. To compare and analyze the ratio of significant wave height from SEAFINE MetOcean data for 6 different platforms with calculated significant wave height from PM Spectrum, JONSWAP Spectrum, and NALL Spectrum respectively.

CHAPTER 2
LITERATURE REVIEW

2.1 HINDCAST METOCEAN DATA

In general, this study are using corrected SEAFINE MetOcean data [5] that involved 6 different platform at 3 regions. SEAFINE MetOcean Data is actually a form of historical data, that have been recorded over more than 50 years of such continuous data and is available for most regions including 6 region used in this study. Unreliability of measured MetOcean data happens due to missing data as a result of faulty measuring equipment during the measuring process resulting in used of SEAFINE MetOcean model data. SEAFINE MetOcean model data is introduced as an alternative to measured data because the data recorded is readily available, reliable and is able to provide long periods of historical MetOcean data. Therefore, SEAFINE becomes a common tool to assess MetOcean information at any locations especially in the South China Sea.

Based on the study conducted previously, SEAFINE MetOcean Data is found to be not as accurate as measured MetOcean data [5]. However, the accuracy of the SEAFINE is improved and correction factors are recommended for three (3) operating regions located in Continental Shelf Malaysia which are Peninsular Malaysian Operation (PMO), Sarawak Operation (SKO) and Sabah Operation (SBO). From the conducted studies, wave height data obtained from the SEAFINE is found to agree well with that of measured data. The correction factors for both SEAFINE wind and wave data are recommended. The adjustment factor reflecting the 95% confidence intervals are adopted to interpret SEAFINE wind and wave data.

Region	SEAFINE Wind Speed Correction Factors					
	NEM	*95% UCL*	*SWM*	*95% UCL*	*InterM*	*95% UCL*
PMO	0.86	1.02	0.92	1.03	0.92	1.00
SKO	1.01	1.10	0.93	1.24	0.95	1.01
SBO	0.98	1.04	0.93	0.98	0.93	0.97

Table 2.0: Correction Factors of Wind Speed during NE, SW and Inter Monsoon Based on 95% UCL

Region	SEAFINE Significant Wave Height Correction Factors					
	NEM	*95% UCL*	*SWM*	*95% UCL*	*InterM*	*95% UCL*
PMO	1.20	1.22	1.15	1.18	1.16	1.19
SKO	0.97	1.03	0.99	1.01	0.99	1.00
SBO	1.05	1.12	1.02	1.04	1.02	1.03

Table 2.1: Correction Factors of Significant Wave Height during NE, SW and Inter Monsoon Based on 95% UCL

2.2 SEASONAL MONSOON

Monsoons were basically effect the climate of wind and wave circulation in Peninsular Malaysia's east coast. A strong southwesterly current were technically caused by the strong seasonal monsoon season at the Continental Shelf Malaysia including east Malaysia coast [6]. In addition, during the southwest monsoon period (May to August), the wind blew from southwest and the circulation of South China Sea generally follow suit while during northeast monsoon period, the wind stress changes dramatically to the opposite direction which lead to the different phenomenon of wind and wave condition happened in both seasonal monsoon seasons. Besides, the current circulation change has also caused the current direction to change. For example, during May, the surface circulation recorded at these time was relatively not as low and weak as compared to surface circulation happened in the month of October. This is actually related to the transition characteristics is differ between both of the monsoon period. Therefore, based on this understanding, the outcomes of the characteristic wind and wave's data are literally based on what seasons or monsoons happened on the time the data are recorded. The different in monsoons conditions will slightly produced different results of wind and wave data. Even though, seems like only wind circulation will be effected when the recorded time facing the different monsoon, but since wave are originated from the blowing of wind over fetch length thus its simultaneously give directly impact of wave generation. The factor generation of waves are basically involved wind velocity, wind duration and fetch length [7].

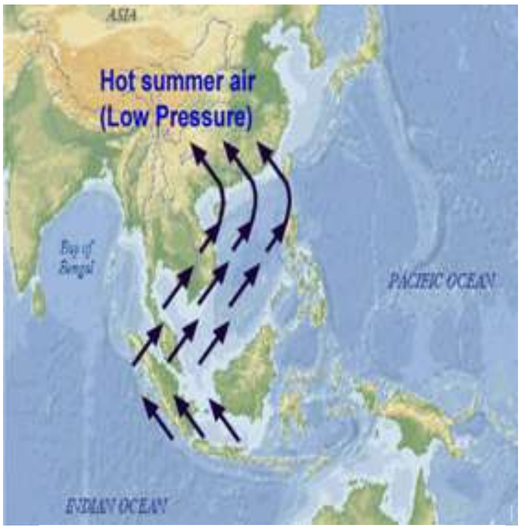


Figure 2.1: Southwest Monsoon

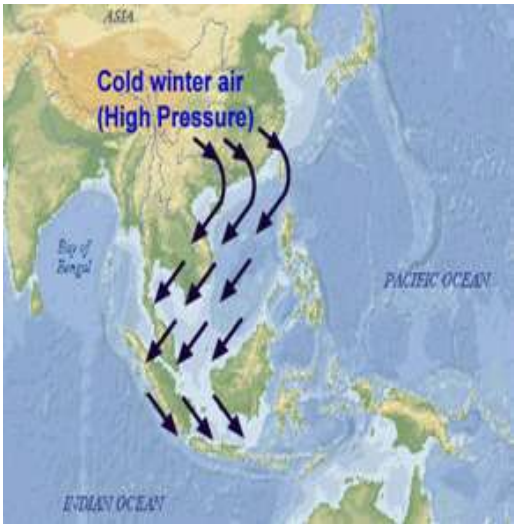


Figure 2.2: Northeast Monsoon

For example, in Japan, they are experiencing four different seasons which are winter, spring, summer, and autumn, as the months of December to February, March to May, June to August, and September to November, respectively. In result, the characteristic of wind and waves will slightly be different for all these seasons. In Malaysia, even though we are not experiencing those seasons, but generally we are having 2 monsoons regimes which are southwest monsoon and northeast monsoon that happened in late May to September and November to March, respectively. These monsoons are mainly caused by land sea temperature differences happened due to heating by the sun radiation as Earth are cycling around sun [9]. In addition, Northeast monsoon bring heavy rainfall particularly to the east coast states of Peninsular Malaysia and western Sarawak, where as the Southwest monsoon normally drier weather. Thus, this will lead to different wind and wave data recorded at the region.

2.3 WIND SPEED AND WAVE HEIGHT DATA

Numerous studies have been carried out related to measured data collected including several kind of parameters such as wind and wave such as Grow Reanalysis of Ocean Wave (GROW) project, West Africa Normals and Extremes (WANE) and Dutch Offshore Wind Energy Converter (DOWEC) project. All this studies are basically to investigate the distribution of metOcean conditions using SEAFINE MetOcean data for many kind of reasons. For example, Horizon Marine located in Brazil conduct a study using SEAFINE MetOcean data to forecast the occurrence of hurricanes. As a result, Horizon Marine able to obtain the model data fits fairly to the measured MetOcean data. But, in order to forecast the variability of the ocean, it is very important to analyze recorded wind and wave variables precisely together with the estimation of the wind and wave parameter.

There are several techniques or theory can be used to evaluate and determining the correlation of wind and wave. Time series plot is one of the basic method commonly used to compare data pattern of different variable. In addition, to understand and analyze the MetOcean data which are the time series data recorded from the sea state, many type of time series models could be used such as Box and Jenkins (1976) for example by using autoregressive (AR) model or autoregressive moving average (ARMA) [10]. Also, various applications were done by using this kind of model as mentioned by various authors such as to analyze the recorded wind data [11], besides there is also needed to analyze wave height data. However, above mentioned model are only applicable for stationary time series in which it means this model is not helpful enough during wave motion in particularly for this study.

Thus, for parameter especially for wave motion, Box and Jenkins (1976) again come out with another time series model; autoregressive integrated moving average (ARIMA) model for standard non stationary time series data analysis. There are also other useful models commonly used other than ARIMA Model in order to analysis wave moving during wave development process such as the autoregressive model with time varying coefficients and generalized autoregressive conditional heteroscedasticity (GARCH) model by [7]. In 2012, collation of offshore wind-wave dynamics were studied by Marine Renewables Infrastructure Network. The study were basically about wind and wave climates for offshore wind operation sites located in two different locations that have been presented in terms of probability distributions by using Weibull distributions for wind speed.

On the other dimensions, [12] also discovered that for reasonably homogeneous and stationary wind fields, fairly narrow band frequency spectrum could be used to described the waves that happened when the wind blows over the water and generate surface waves. Pierson-Moskowitz Spectrum Model is formulated based on case study at North Sea which referred as Fully Developed Sea. In the end, the study concluded that the curves for the data used were seen to be very similar when comparing the dependence of significant wave height Hs to wind speed. This suggests that values are based on fatigue-lumped Hs values which might induce some dependence to structural parameters but a generic relation might still exist. Nevertheless, an analytical function was fitted to the applied data. Weibull distributions found to be most reasonable choice compared to others theory such as Narrow-band Gaussian models by Naess (1985), and also Kolmogorov test, Jahn Wheeler and the Rayleigh Stokes.

Water depth, wave height and period are the example of the specific environmental parameters that being a dependency parameter for water wave theories whereby being produced in the development of wave studies. Several regular wave theories have been developed into describing the water kinematics such as the basic Airy wave theory, Stokes high order theories, Cnoidal wave theory and Stream Function wave theory where these theories are linear and non-linear which have been mentioned in Chakrabarti's publication (1968) which can be described in Figure 2.3. From this representation it can be clearly seen that the formation of irregular waves is due to regular waves and through this basic concept the wave shape produced by irregular waves is a resultant of all the regular shape waves. On the other hand, N. Haritos (2007) explains that in irregular ocean sea state character's modelling, it is often depicted as the superposition of a number of Airy wavelets of varying amplitude, wavelength and direction which all together models out the irregular character of waves. Much comprehensive understanding on waves can also be done through the understanding of energy spectrum which will be discussed later.

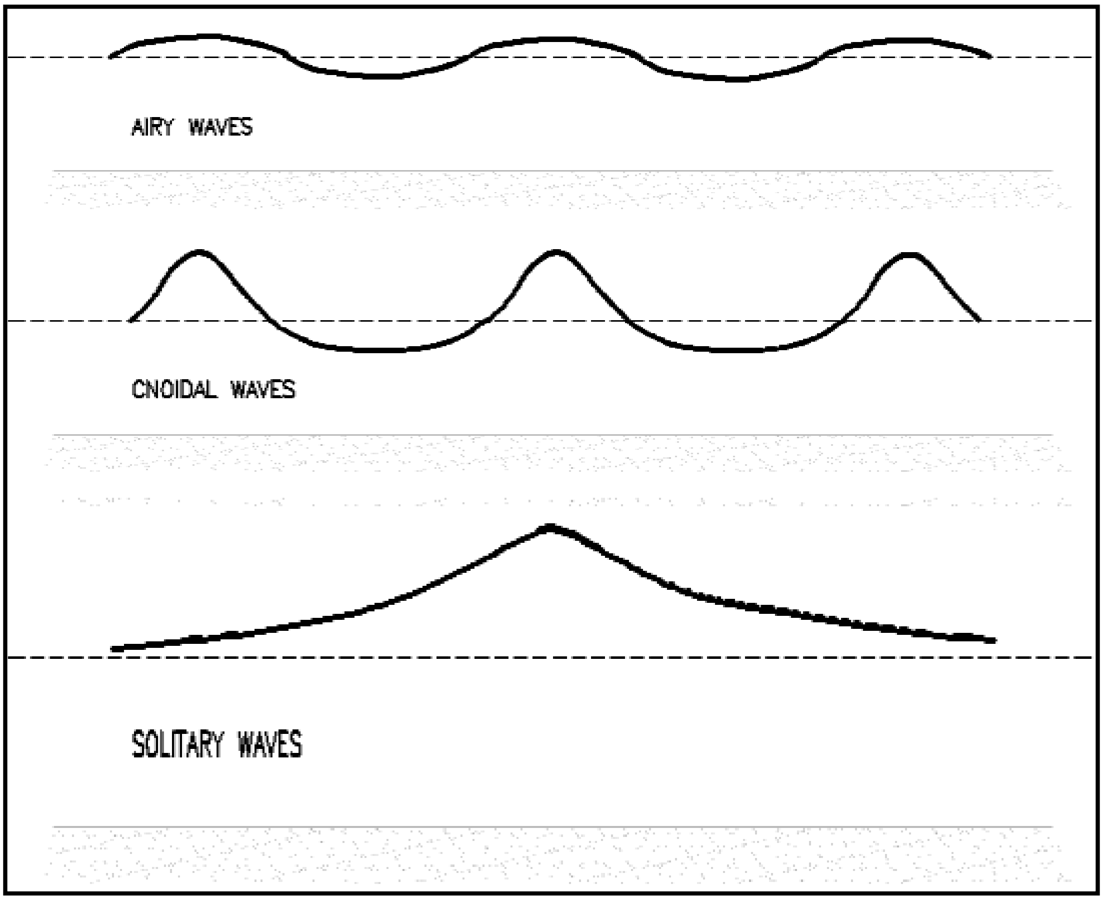


Figure 2.3: Example of regular and irregular wave

(From top: Airy Waves, Cnoidal Waves, and Solitary Waves)

2.4 SEA STATE STATUS

According to [8], by determined of wind speed and fetch duration, only after wave reach their maximum size, waves will continue to grow in as depends on the wind and fetch respectively. At these stage of wave growth, under the existing wave conditions waves stop growing in size because the energy supplied by the wind equals the energy lost by wave breaking and leaving the fetch area. This sea at this state is termed a fully developed sea state condition. Besides that, a sea is classified as fully developed when maximum fetch and maximum duration are reached for a given wind speed. In addition, for a fully-developed sea, significant wave height solely is a function of wind speed. Significant wave height are defined as average height of the largest 1/3 of the waves which could be refer in figure 2.4 below.

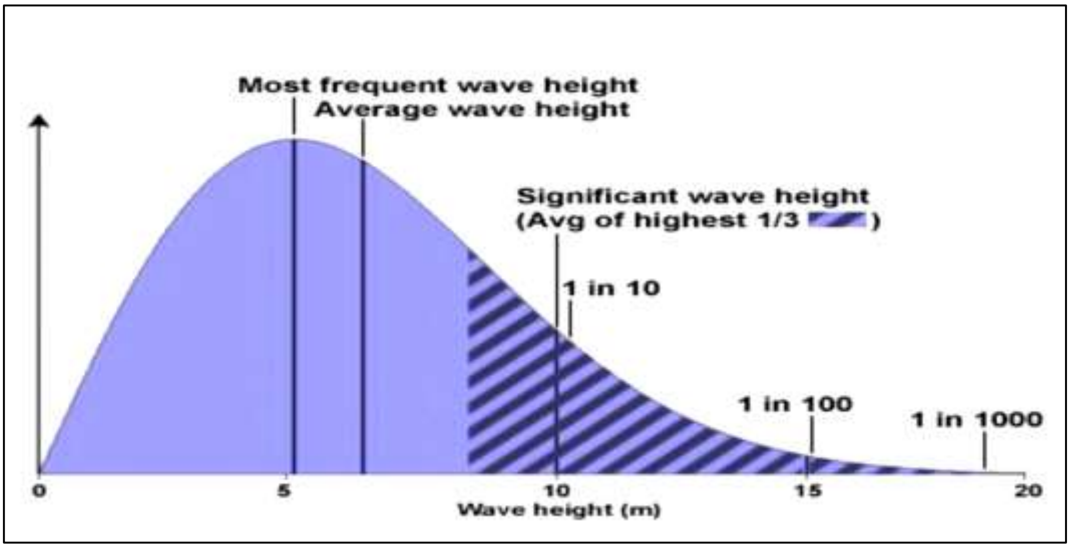


Figure 2.4: Statistical Distribution of wave height

(Source: C.L. Bretschneider, 1964)

In addition, studies done by [3] by using the data obtained by Moskowitz [1964] which referred for the spectrums of fully developed seas specifically for a wind speeds from 20 to 40 knots (10.29 to 20.58 m/sec), are used to test the similarity hypothesis and the idea proposed by Kitaigorodskii [1961]. Based on the study, [11] stated that the power spectrums for all classified fully developed sea status conditions should be of the same shape even if the parameters were plotted in a certain dimensionless way in which could be used to have better analysis comparison for this study between other wave spectrum model. However, the results of the plotted parameters when errors in the wind speed, the sampling variability of the data, and the anemometer heights are considered, suggest a spectral form that is a compromise between the various proposed spectrums and that has features similar to many of them. Therefore, [3] proposed to improved wind speed measurements which should be taken at several elevations and averaged over longer time intervals. Besides that, in order to have a better wave data, it should be taken for longer time intervals and analyzed so as to better fit the procedures. These requirements of wind speed measurement are actually needed the greater precision could be determined from the form of the spectrums of fully developed wind seas and seas limited by either fetch or duration.

W.H. Michel (1968) claims that waves in the sea are never regular as it does not depict itself in a series in uniform waves of constant height and length which leads to have the property of irregular and random wave at the same time. With these irregular and non-constant irregular with respect to their direction, amplitude and frequency, wind wave were considered as a very complex natures. In W.H. Michel's publication on sea spectra, since wave a classified as undistinctive pattern, thus the irregular wave are characterized not through the wave shapes but by using the energy spectrum. S.K. Chakrabarti (1986) interprets the wave energy spectrum model as a mathematical spectrum model where the model is based on parameters such as wave height or wave period.

Currently, the present spectrum model has its own sea state classification. The most common and well-known spectrum is the Pierson-Moskowitz (PM) (1964) model spectrum whereby it is a single based parameter which based on wind speed or significant wave height. This energy spectrum model has been extensively used in various application in the design parameter used especially for offshore structures. The PM Spectral model scientifically describes a fully-developed sea as where wind speed, fetch and duration parameter were taken into consideration. As PM Spectrum is a fully developed sea, a final empirical formula of the spectrum can be written as follows:

$$S\ (w) = \propto g^2 w^{-5} \exp(\ -0.74\ \left(\frac{wU_{\omega}}{g}\right)^{-4})$$

For partially developed sea application, JONSWAP Spectrum Model was developed by Hasselman (1973) during a joint North Sea wave project whereby usually considering as a two-parameter spectrum. In W.H. Michel, partially developed seas are the first wave generated that are those of short length and later as wind continues blowing, long and longer waves are generated and eventually the system becomes stable where no effect is produced no matter how much longer the wind blows over any area, until this final condition it is known as fully developed sea. The formula for the JONSWAP Spectrum can be formulated as follows:

$$S\ (w) = \propto g^2 w^{-5} \exp\left(\ -1.25\ \left(\frac{w}{w_{\circ}}\right)^{-4}\right) \gamma^{\exp\left(-\frac{\left(\frac{w}{w_{\circ}}\right)^{2}}{2\ \tau^2 w_{\circ}^{2}}\right)}$$

Besides, NALL Spectrum also being used in this research study which refer to partially developed sea that used angular frequency and fetch length as an inputs. In general, NALL Spectrum Model was formulated and built-in Malaysian Regional Wave Parameter.

$$S(f) = \frac{\beta x_r^2}{f^5} \exp\left[-1.25\left(\frac{f}{f_p}\right)^{-4}\right] \gamma^{\exp\left[-\frac{(f-f_p)^2}{2\sigma^2 f_p^2}\right]}$$

CHAPTER 3
METHODOLOGY

3.1 SOURCES OF DATA

The main data sources being used for this study are wind and wave MetOcean data recorded at 3 different regions that including 6 different platforms located at these regions. This data were recorded using measuring instrument placed at the offshore operations site. Interconnected anemometers weather vanes that have been installed 10m above sea level. This instrument were used to measure and record wind speed and wind direction while wave buoys were installed at the platform to record wave height and wave direction respectively. Meanwhile, the selected locations of offshore platform are basically located at South China Sea which technically six different locations as illustrate below.

Figure 3.0: Location coordinates of PMO, SKO and SBO station

ace to measure the instrument covered for all directions from North to South and vice versa.

In addition, by installing the interconnected anemometer, following characterized wind climate can be obtained:

1) mean speed
2) wind direction
3) wind stress
4) Extreme wind speed with 1 year and 50 year return period.

For the wave data which recorded by installing wave buoys instrument, following are the characteristic wave climate that can be obtained:

1) significant wave height, Hs
2) Peak period, Tp.
3) wave direction
4) extreme value of Hs with Tp (with 1 and 50 year return period)

In particular, significant wave height and maximum wave height data were recorded by installing buoys at the operation site that recorded data for particular locality. Significant wave height is defined as the mean wave height (trough to crest) of the highest one third all waves for a given timeframe data while Maximum wave height represents the peak wave height recorded over a given timeframe. In addition, the data obtained are based on 1-hour interval located at uniform grid of 25km grid embedded with a very high resolution fine grid with a grid spacing of about 6km as stated by [5].

3.2 TIME SERIES ANALYSIS

As mentioned, the sample of the data were recorded in time, seconds, this interprets that the data is inn the time domain. In relation to the time domain, a specific term of analysis can be determined through the MetOcean data which is Time Series Analysis. The time series is actually a statistical set of data which usually collected at linear intervals [14]. Time series data occur naturally in many application areas such as in environment; daily or monthly rainfall data being collected at regular intervals. Also stated by [14], time series is a set of observations data of the random variable collected over time. Besides that, in further explanation [14], also stated that trend, seasonal effects, cycles and residuals are the elements involved in describe the decomposition of time series data.

Time series on its own is a vast field of descriptive statistics in which the sets of data are natural occurring and can be used in many fields of application such as environmental, finance, economics and many more. The common reason of the usage of a time series analysis is due to the stochastic nature of the process involved, for this research, as explained, waves are natural occurring and stochastic in nature which fits the criteria of a time series. A time series is a combination of four element which are trend, seasonal effects, cycles and residuals and therefore understanding each of this element could lead to closer understanding and comprehending the time series of a set of data. From here much can be used from the findings, such as future prediction and outcomes which is widely used in stock exchange for such benefits. A further depth understanding of the four elements can be explained as such:

1. Trend : Long term movement of mean / average
2. Seasonal Effects : Cyclic fluctuation related to period / actual calendar
3. Cycles: Other cyclic fluctuation (business cycles etc.)
4. Residual : Random / Systematic fluctuations

However, before moving to further statistical approach, a plot on the time series must be conducted in order to observe and visualize the existing time series on determining the representation of the existing data. A time series plot can be represented in Figure 3.1 whereby it is represents the sample of time series plot of available wave data.

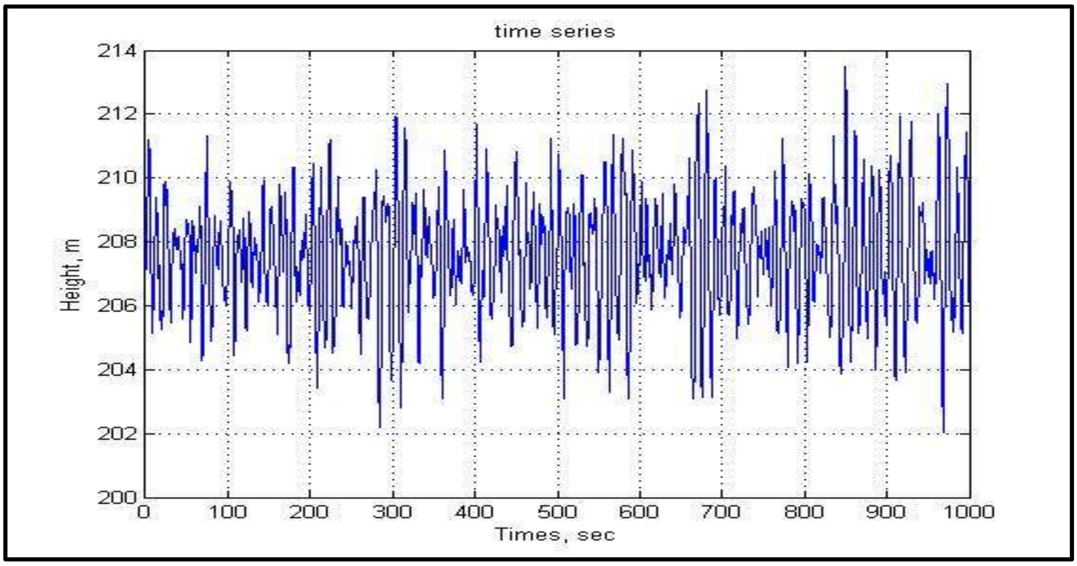


Figure 3.1: Example of random time series plot

Based on the time series plot, it can be seen that nothing can be deduced because the important parameters are not identifiable. Therefore, an extended approach in identifying the important parameters are conducted to make this visible and clearly identifiable. This approach is simply observing the input data in a different domain which is the Frequency Domain.

3.3 MATHEMATICAL SPECTRUM MODELS

Sverdrup and Munk (1947) introduced the concept of significant wave height as the average of the highest one-third of all waves in a particular sea state. In the spectral analysis, the significant wave height is related to the total energy content of the wave spectrum. After a spectral plot are achieved by referring to formula of PM Spectrum and JONSWAP Spectrum, the derivation of significant wave height of the region is done through simple computation of formula as by finding the equivalent value of the area under the spectral plot. This value is then related to the significant wave height through a basic formula which is explained in Chakrabati's publication:

$$\boldsymbol{Hs} = \mathbf{4}\sqrt{\mathrm{m}_{\circ}}$$

Whereby $m_{\circ}$ is the total area under the wave energy density spectrum and Hs is the calculated significant wave height.

After simply formulate and plot both the PM Spectrum and JONSWAP Spectrum respectively, the significant wave height from both wave energy density are then being compare and analysis with the respective recorded Hindcast MetOcean data for the referred platform.

PM Spectrum Model:

$$\boldsymbol{S\ (w) = \propto g^2 w^{-5}\, \mathbf{exp}(\,-0.74\ \left(\frac{w\underset{\smile}{U}}{g}\right)^{-4}\ )}$$

Where;

α = 0.0081 (Phillips constant)

ω= angular frequency

$\underset{\smile}{U}$= Wind Speed

JONSWAP Spectrum Model:

$$\boldsymbol{S\ (w) = \propto g^2 w^{-5}\, \mathbf{exp}\left(\,-1.25\ \left(\frac{w}{w_{\circ}}\right)^{-4}\right)\gamma^{\mathbf{exp}\left(-\frac{\left(\frac{w}{w_{\circ}}\right)^{2}}{2\,\tau^2 w_{\circ}^{\ 2}}\right)}}$$

Where;

τ = shape parameters

ω= angular frequency

ω_p = peak angular frequency

γ = peak enhancement factor

NALL Spectrum Model:

$$S(f) = \frac{\beta x_r^2}{f^5} \exp\left[-1.25\left(\frac{f}{f_p}\right)^{-4}\right] \gamma^{\exp\left[-\frac{(f-f_p)^2}{2\sigma^2 f_p^2}\right]}$$

Where;

$$\beta = \left[3.68 + 0.5376\gamma - \frac{2.96}{1.9+\gamma}\right]^{-1}$$

Recommended gamma, = 1

$x_{r1} = 0.021\ (PMO)$

$x_{r2} = 0.018\ (SKO\ \&\ SBO)$

$\sigma = 0.07 \quad for\ f \leq f_p$

$\sigma = 0.09 \quad for\ f > f_p$

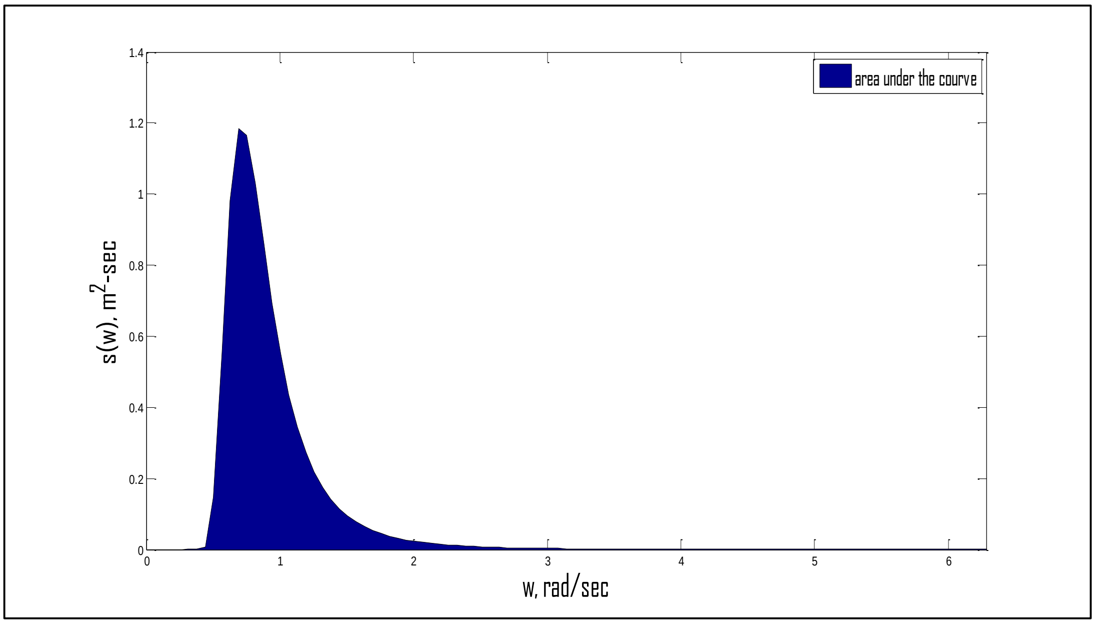


Figure 3.2: Example of area under the curve of energy distribution of PM Spectral model

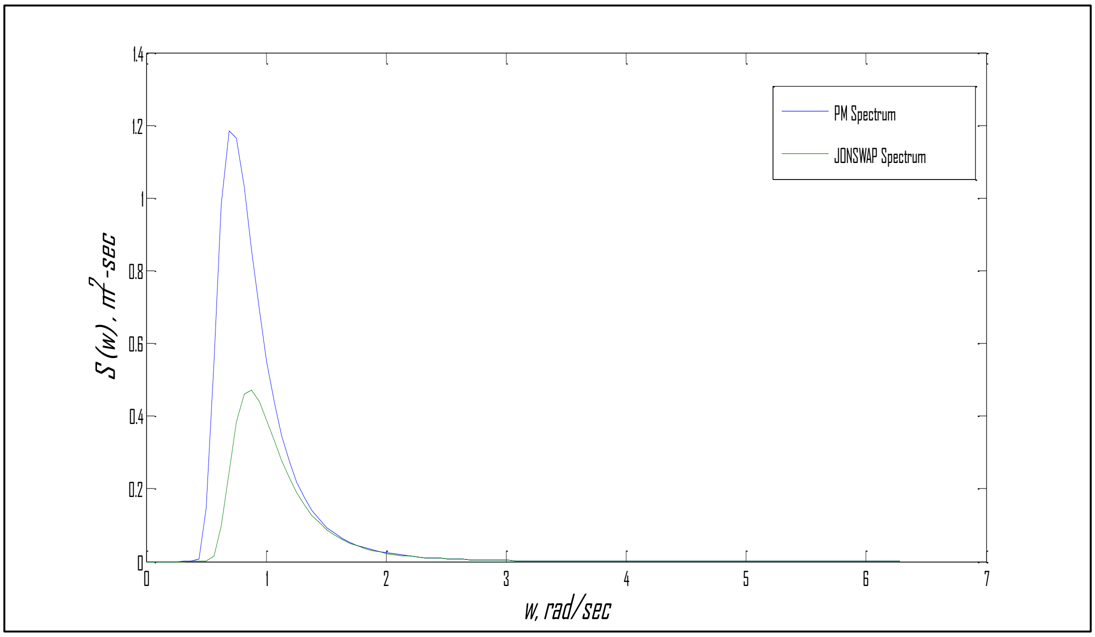
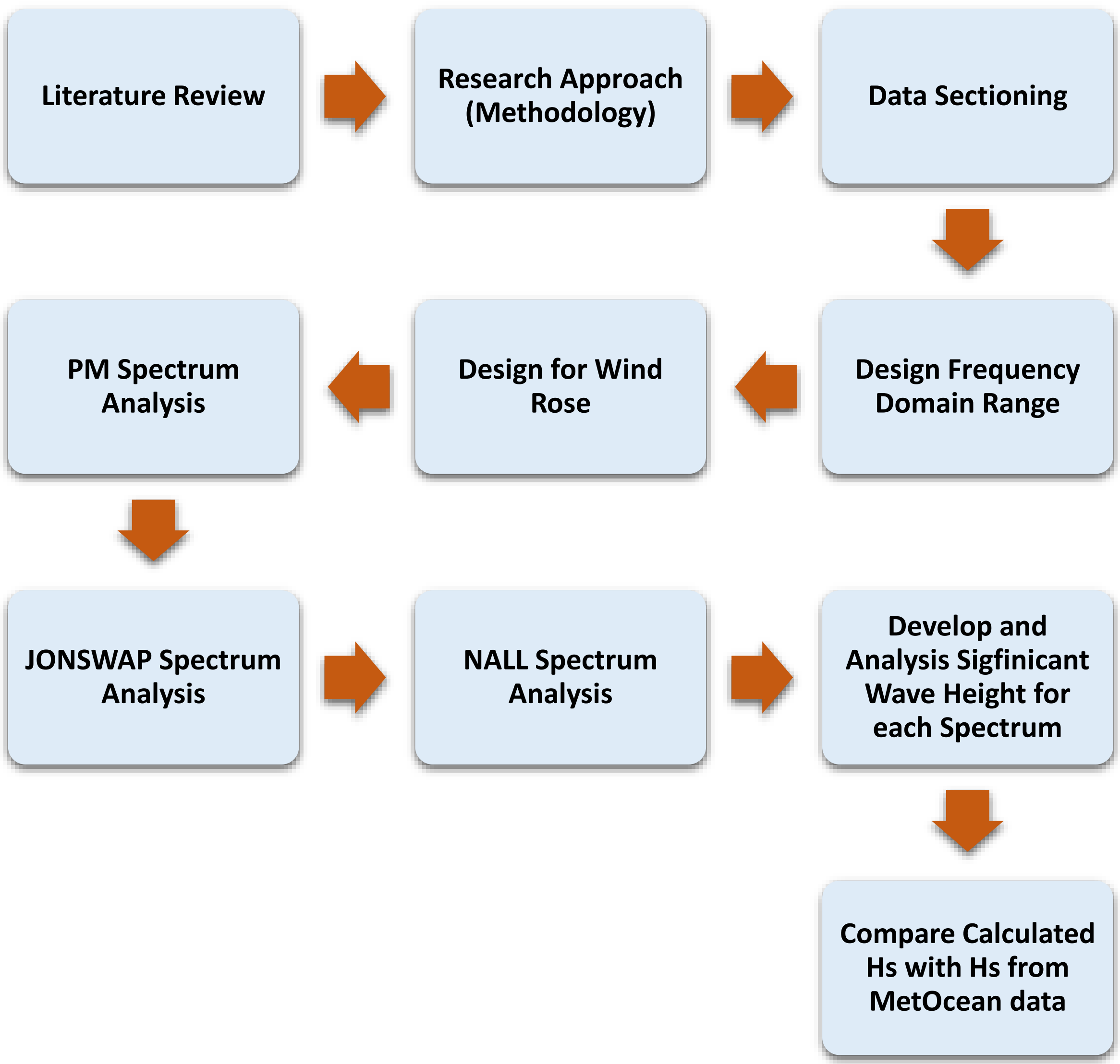


Figure 3.3: Example of energy distribution of spectral model

3.4 PROJECT FLOW CHART



3.5 GANTT CHART / MILESTONE

The following is a project timeline illustration throughout the Final Year Project where the Key Milestone are highlighted out in the Gantt chart.

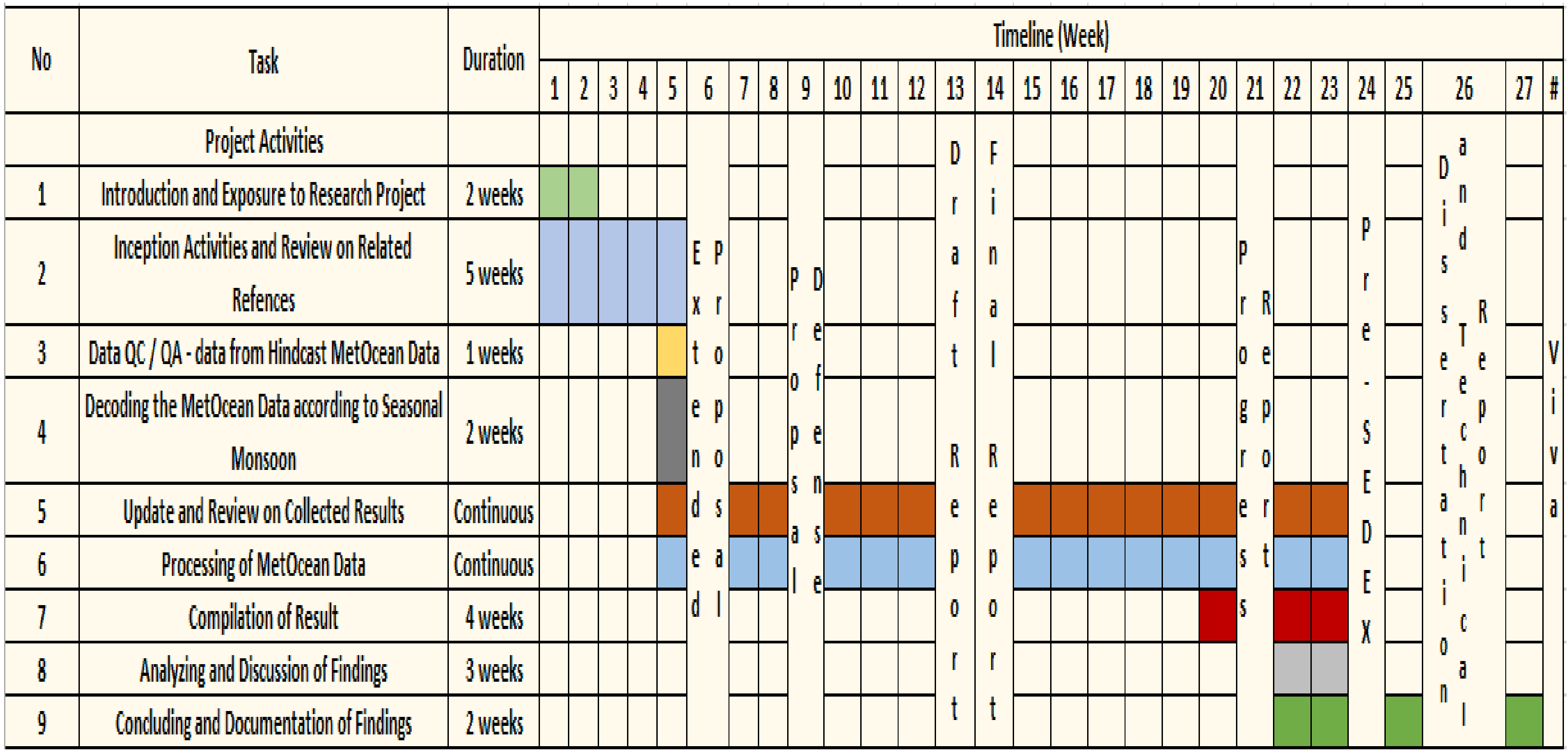


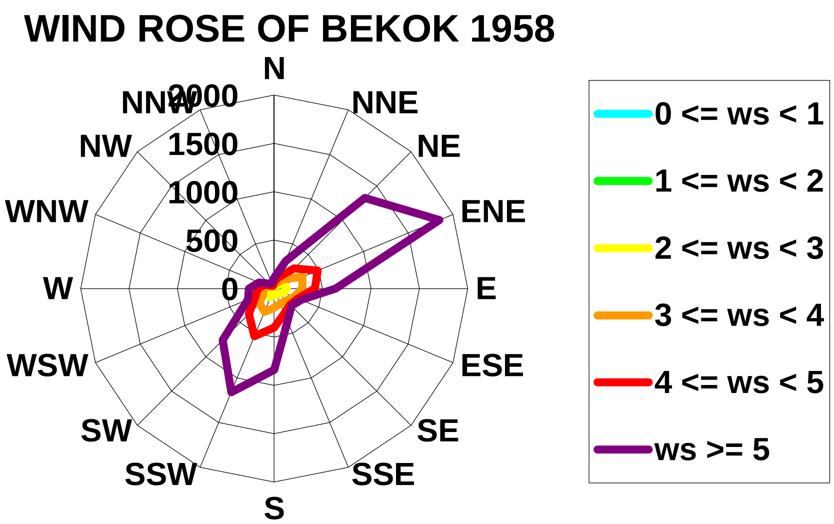
Figure 3.4: Project Gantt chart

CHAPTER 4

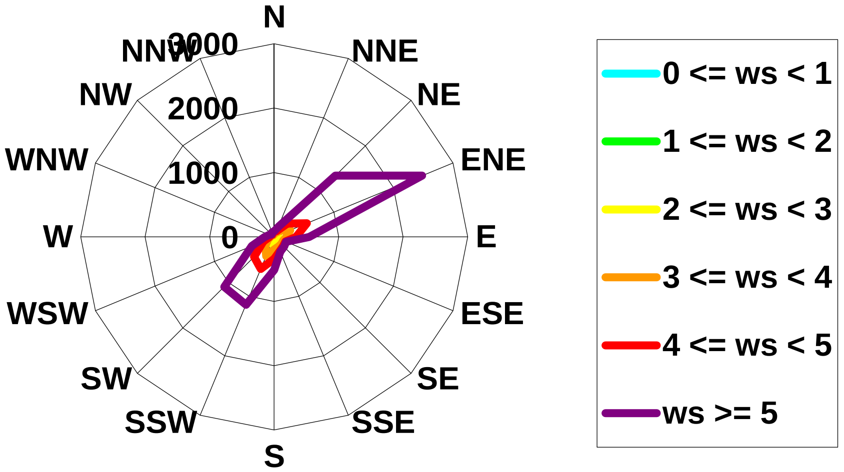
RESULTS AND DISCUSSION

In relation to the conducted research project, much progress has been made and in arriving to the findings of the sea state of Malay Basins. As mentioned earlier, the current research project used SEAFINE MetOcean Data recorded at 6 different places that covers for region of PMO, SKO and SBO, in which the specific data region placed which are Dulang and Bekok at PMO, Erb West and Semarang at SBO, and Tukau and Baronia at SKO. A complete study can be done with the presence of the representative data at any location around the South China Sea region since it covered a large area that involved six countries which are Brunei, China, Malaysia, Philippines, Taiwan and Vietnam. However, at the current stage of findings, it can be seen that not much variation with relation to the difference in region when wind rose of each region were plotted. Form the wind rose chart, all the platform significantly shows the dominant wind speed at Northeast direction. In a more descriptive explanation, in achieving the comparable interpretation for all the platform, the data of 10years gap were also analyzed for wind rose to get the comparable analysis. Thus, the result of the chart analysis are shown as follows:

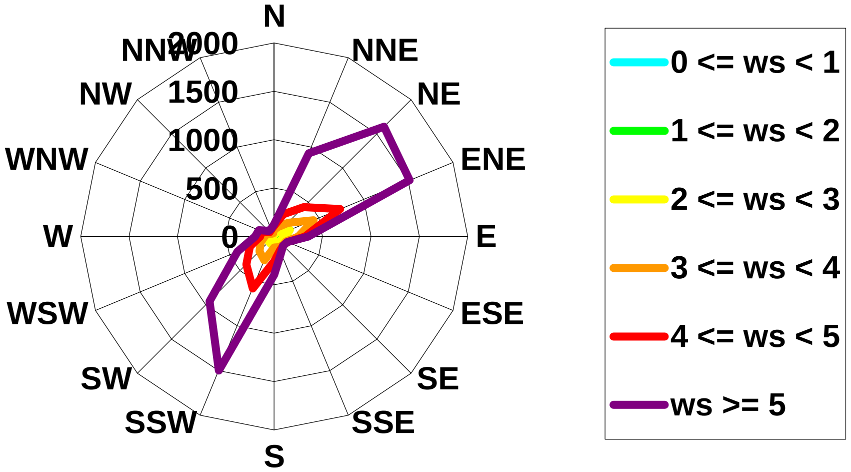
I. PMO BEKOK (1958, 1968, 1978, 1988 and 1998)



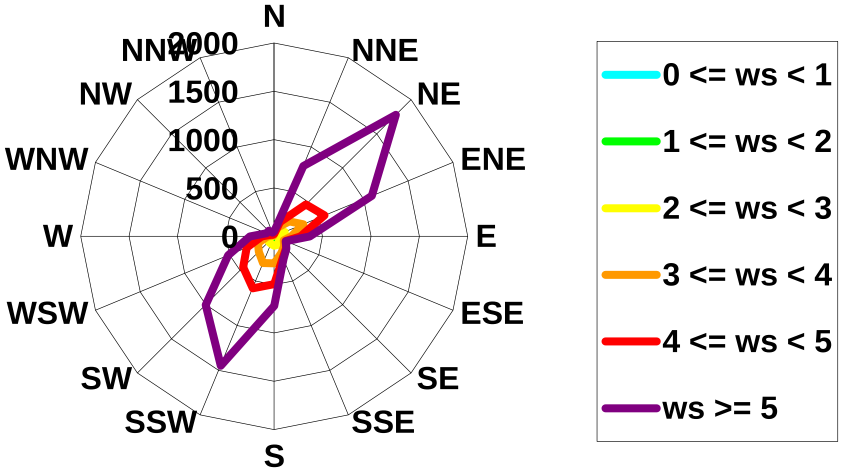
WIND ROSE OF BEKOK 1968

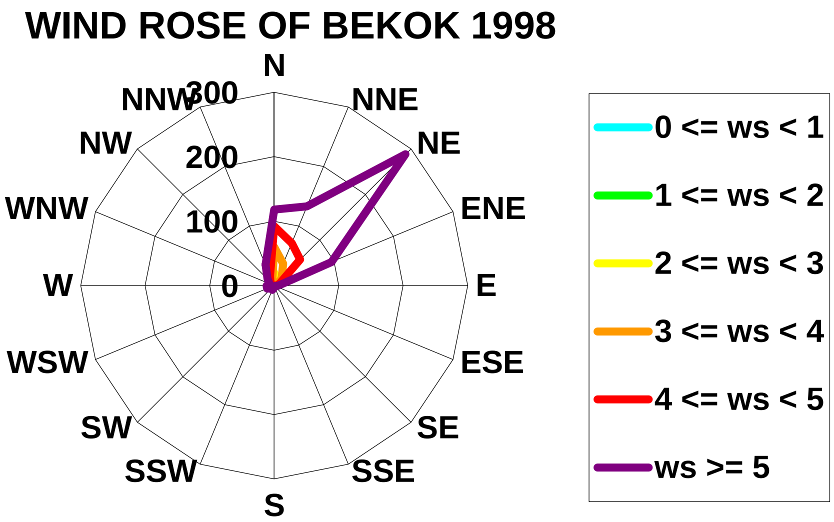


WIND ROSE OF BEKOK 1978

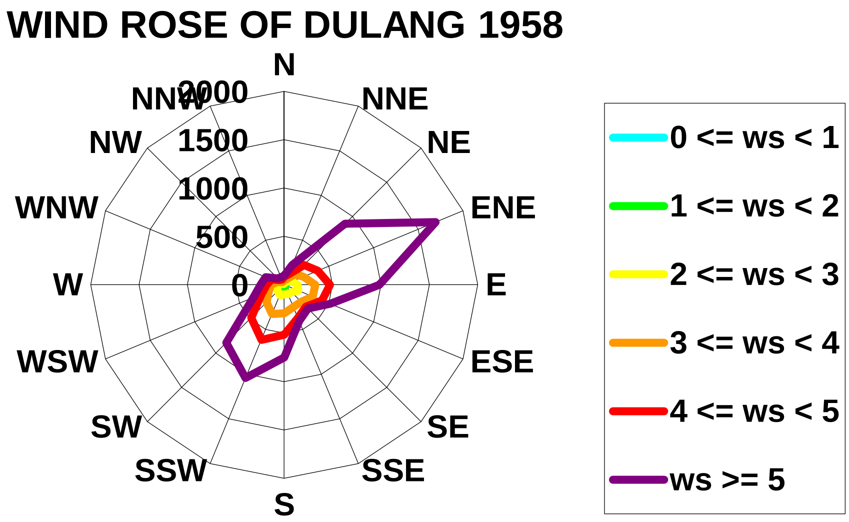


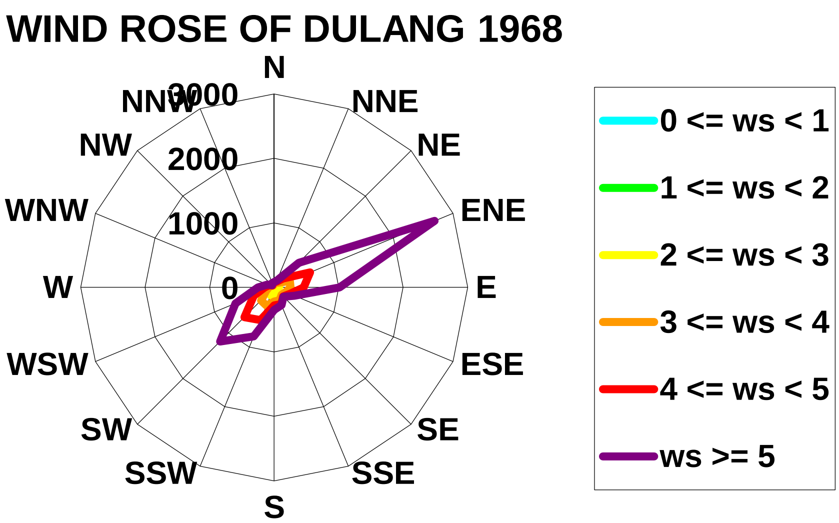
WIND ROSE OF BEKOK 1988

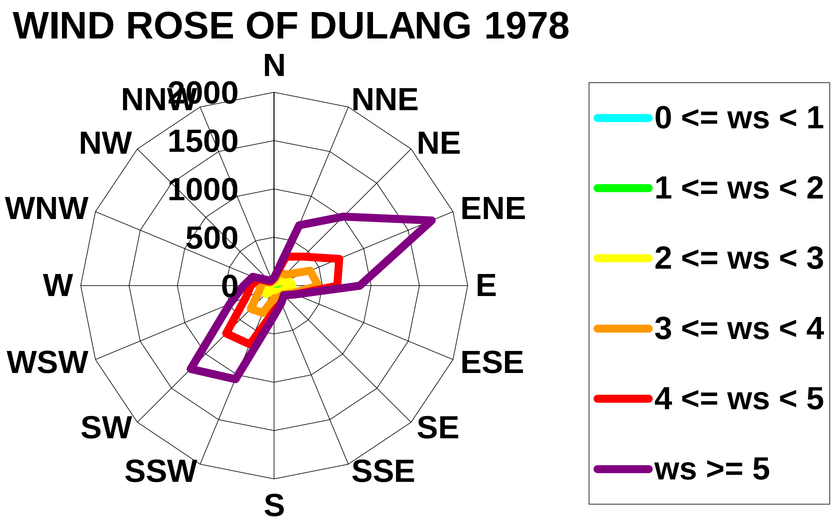




II. PMO DULANG (1958, 1968, 1978, 1988 and 1998)






WIND ROSE OF DULANG 1978
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3 <= ws < 4
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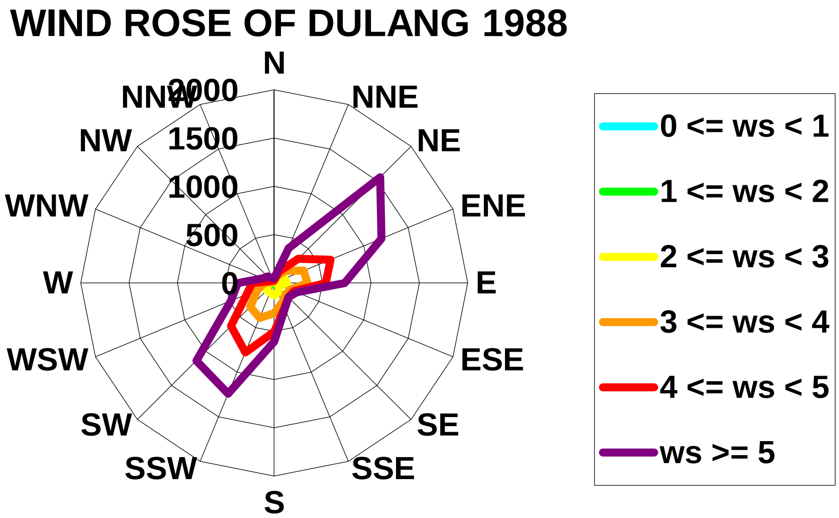
ws >= 5


WIND ROSE OF DULANG 1988
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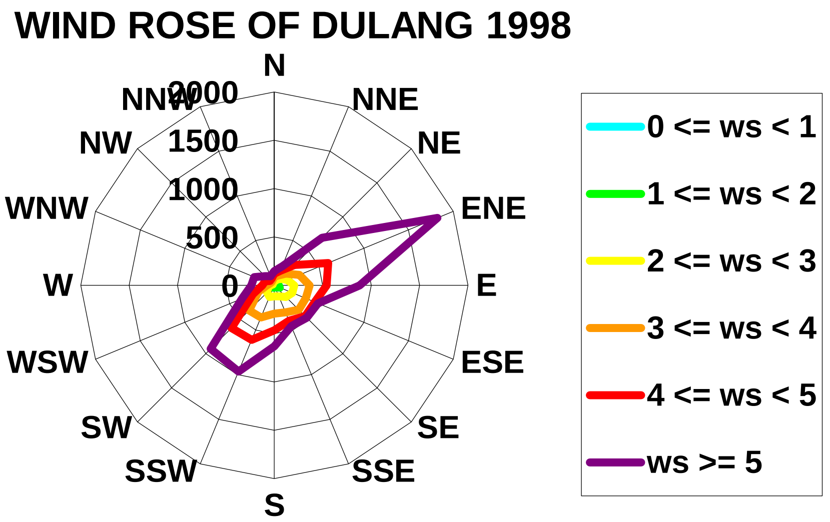
ws >= 5


WIND ROSE OF DULANG 1998
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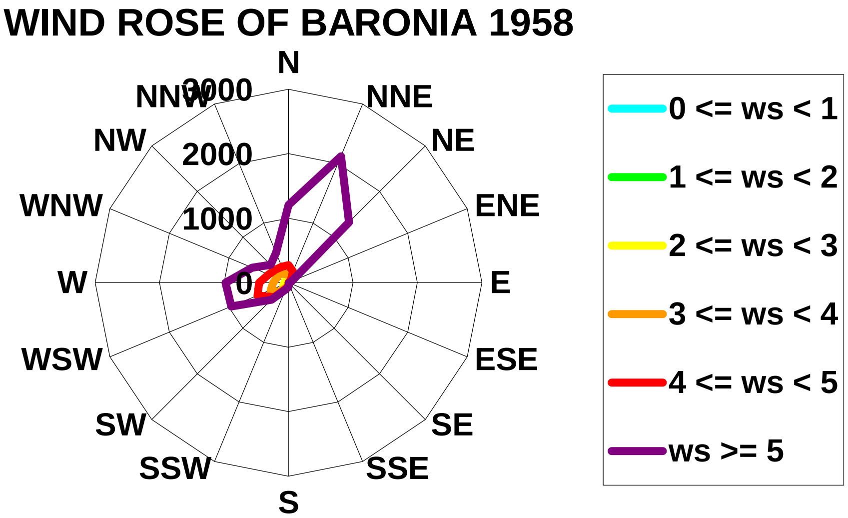
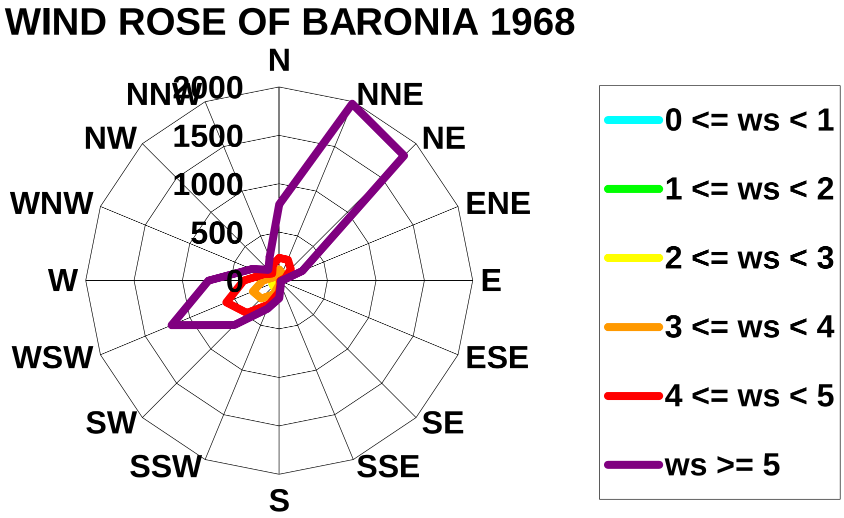
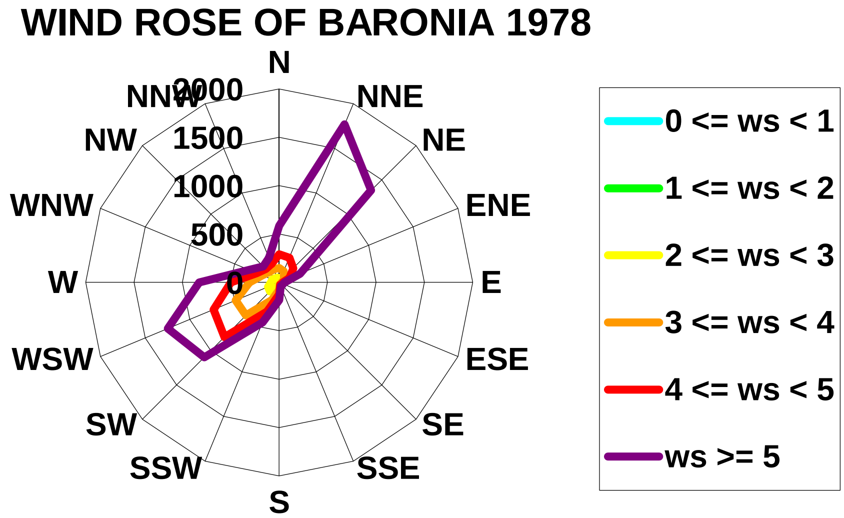
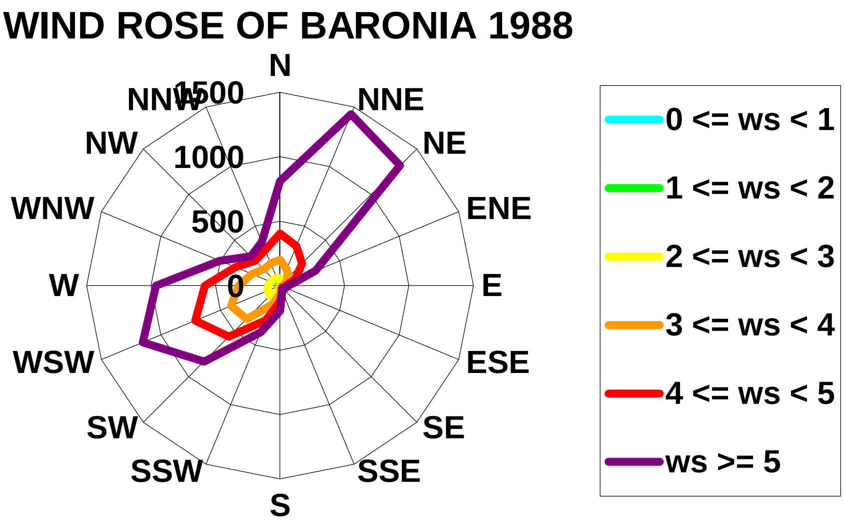
ws >= 5

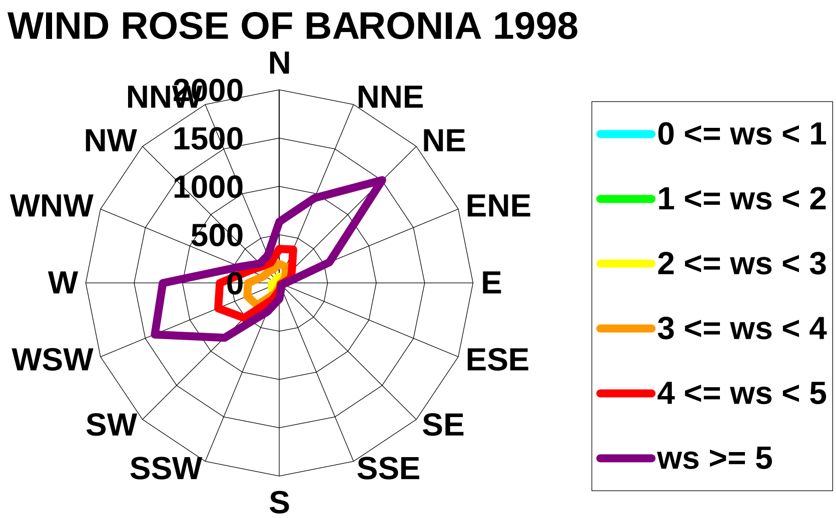
III. SKO BARONIA (1958, 1968, 1978, 1988 and 1998)



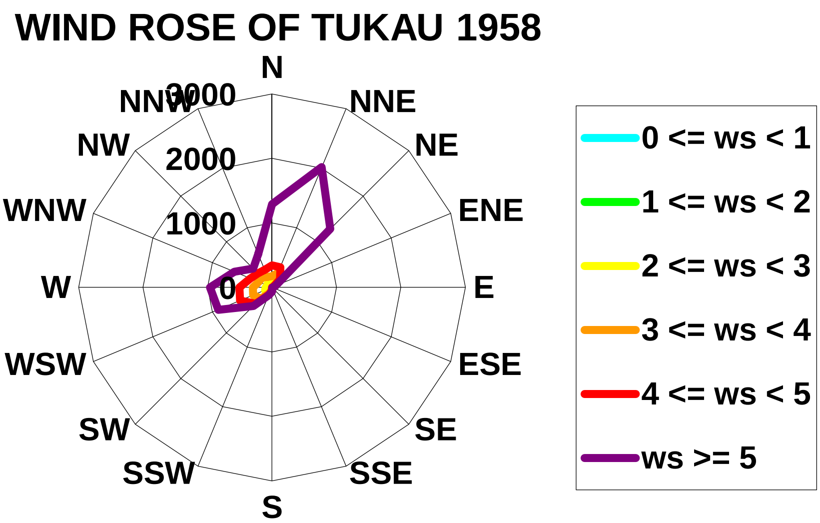




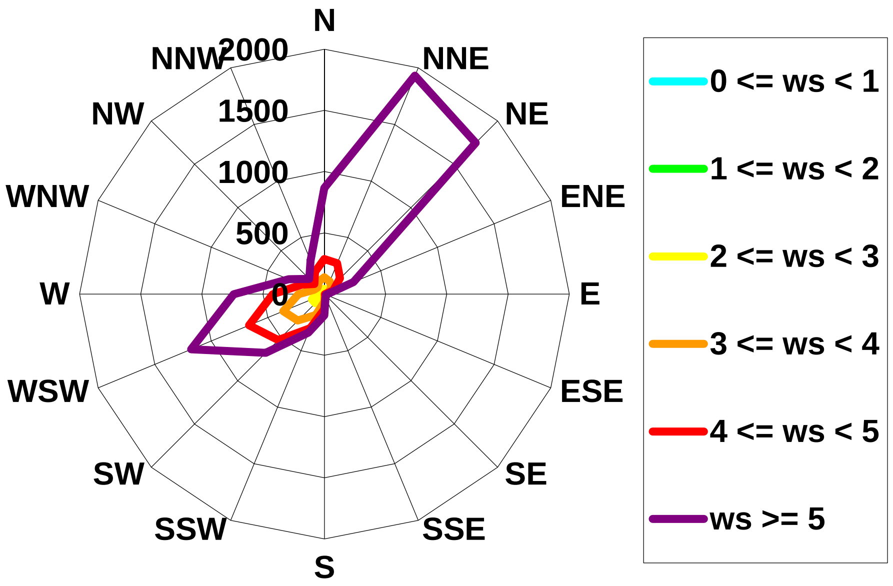




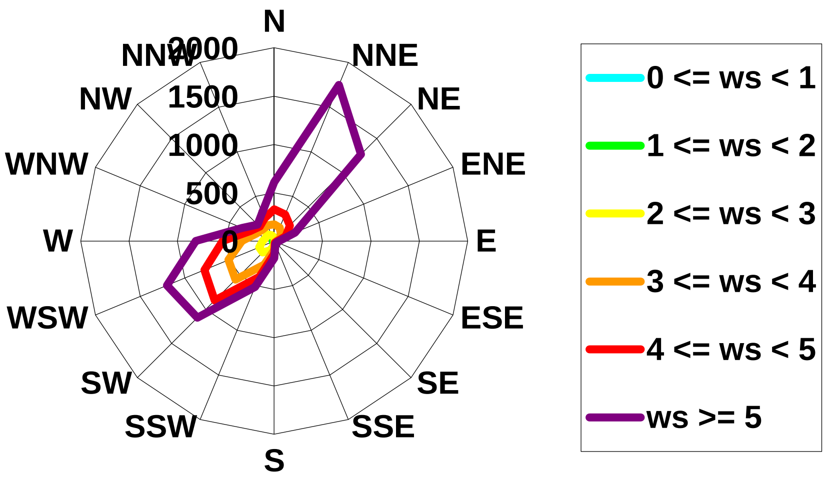
IV. SKO TUKAU (1958, 1968, 1978, 1988 and 1998)

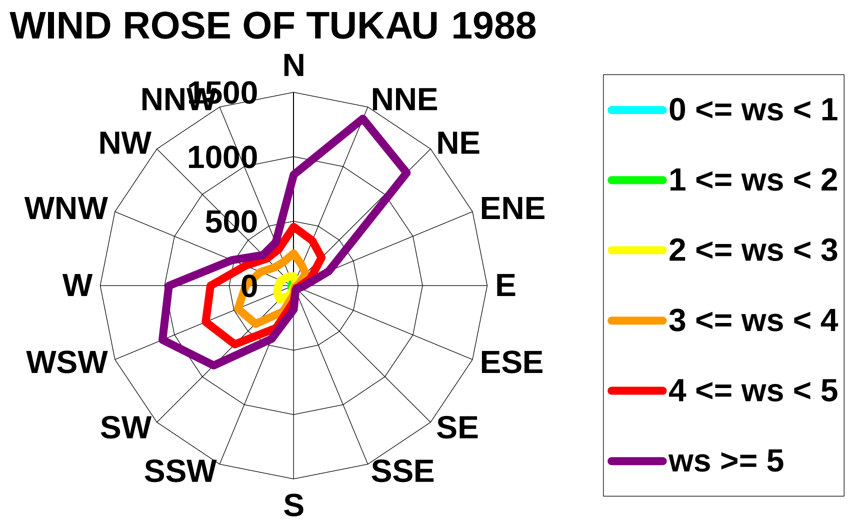


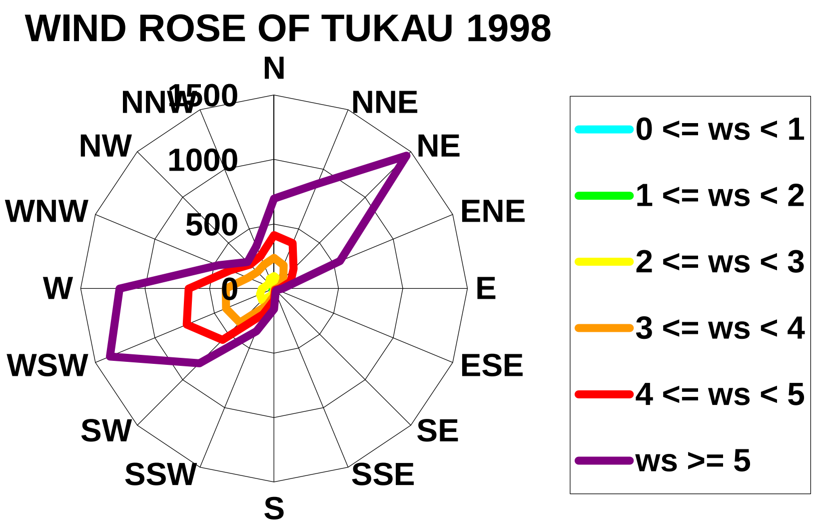
WIND ROSE OF TUKAU 1968



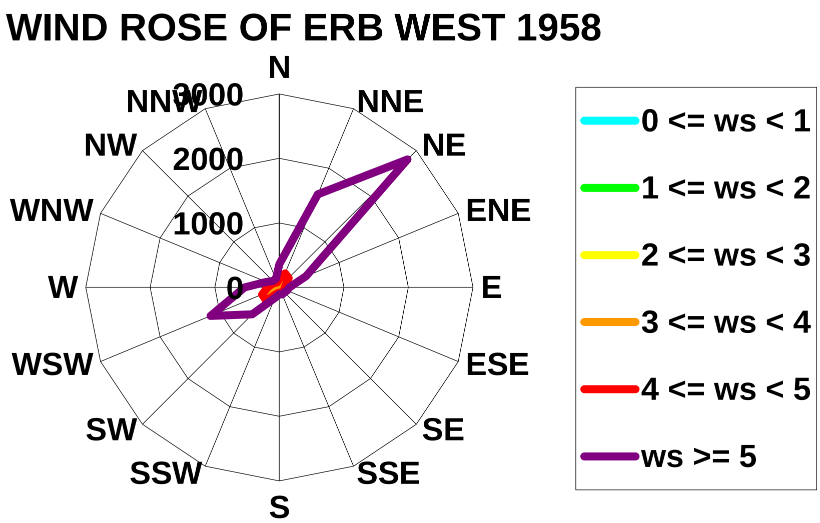
WIND ROSE OF TUKAU 1978

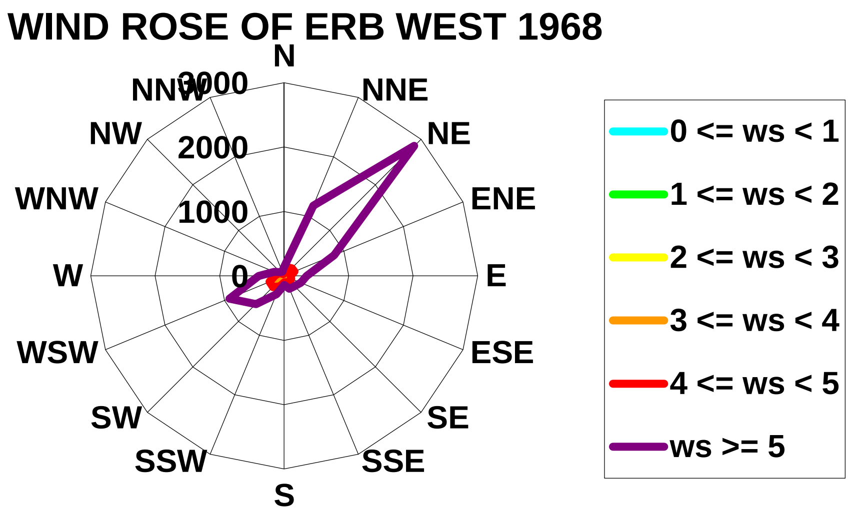






V. SBO ERB WEST (1958, 1968, 1978, 1988 and 1998)




WIND ROSE OF ERB WEST 1968
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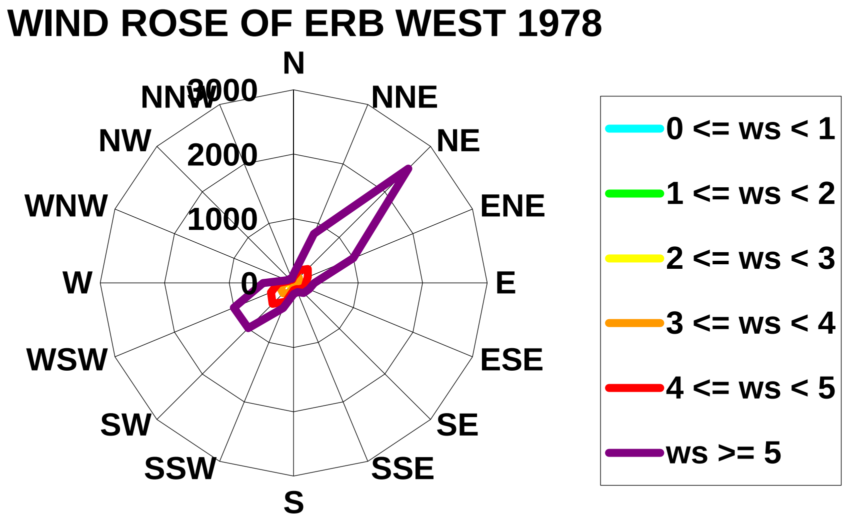
4 <= ws < 5
ws >= 5


WIND ROSE OF ERB WEST 1978
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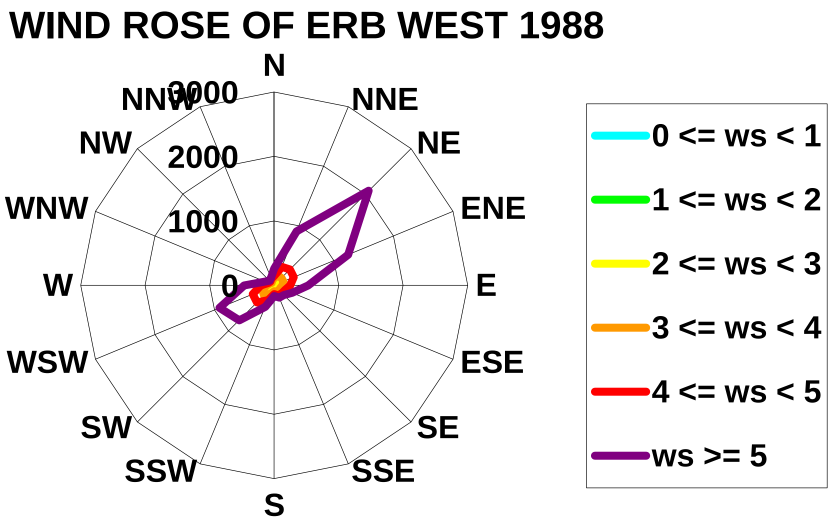
2 <= ws < 3
3 <= ws < 4
4 <= ws < 5
ws >= 5


WIND ROSE OF ERB WEST 1988
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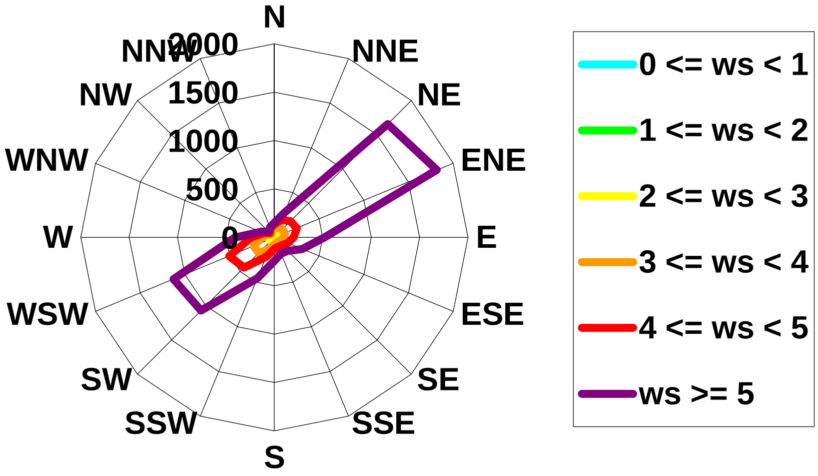
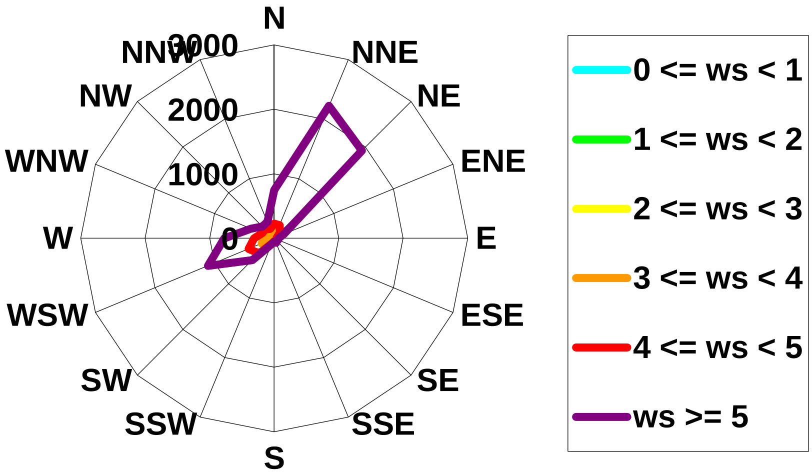
2 <= ws < 3
3 <= ws < 4
4 <= ws < 5
ws >= 5

WIND ROSE OF ERB WEST 1998

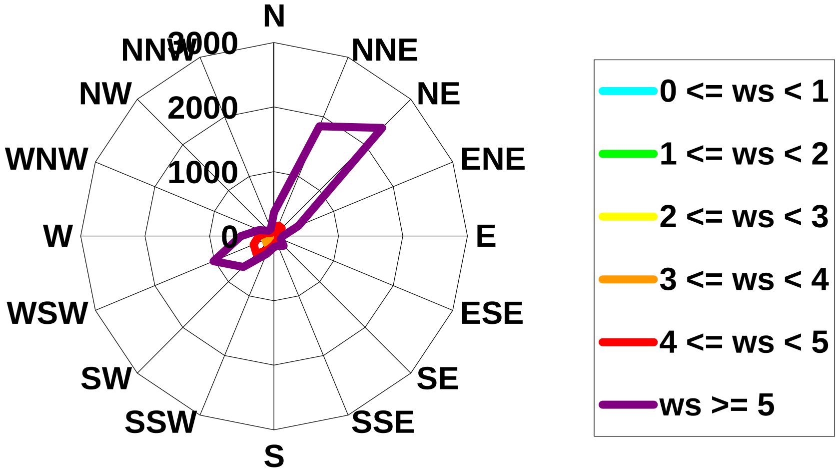


VI. SBO SEMARANG (1958, 1968, 1978, 1988 and 1998)

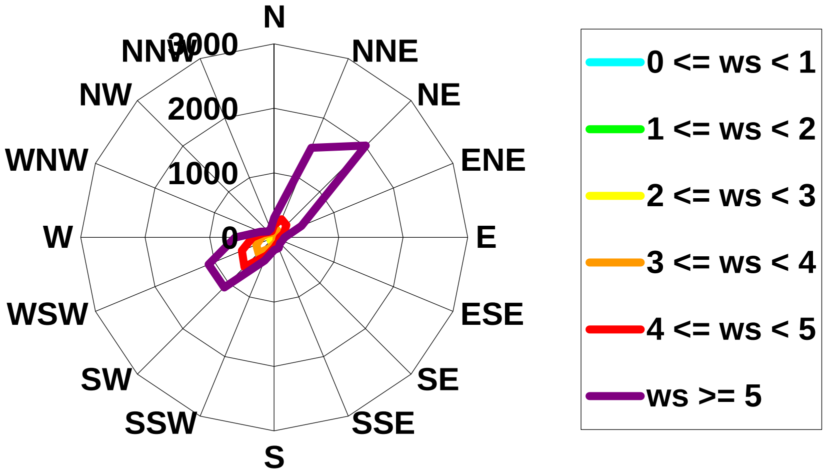
WIND ROSE OF SEMARANG 1958



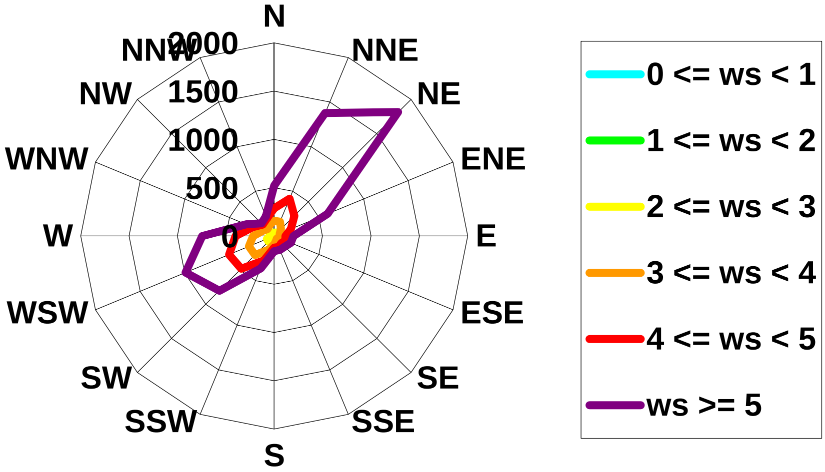
WIND ROSE OF SEMARANG 1968



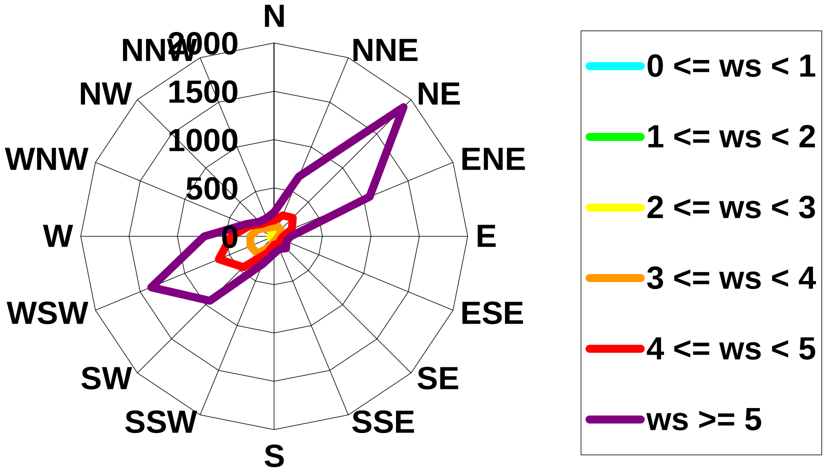
WIND ROSE OF SEMARANG 1978



WIND ROSE OF SEMARANG 1988



WIND ROSE OF SEMARANG 1998



For the sea states study, formulation of spectral plots; PM Spectrum, JONSWAP Spectrum and NALL Spectrum are formulated respectively using Matlab Software. The data are compared with the same range wind speed and frequencies domain range. Therefore, the data needs to be analyze first using each spectrum formula with specific frequencies and only after that spectral plots are developed using Matlab Software. The following represents a spectral plot for a data of Bekok (PMO Region) within a year of 1958 recorded at the location. The various color shown in the plotted graph is actually representative of approximately 8780 data recorded in hourly mean for 1 year interval.

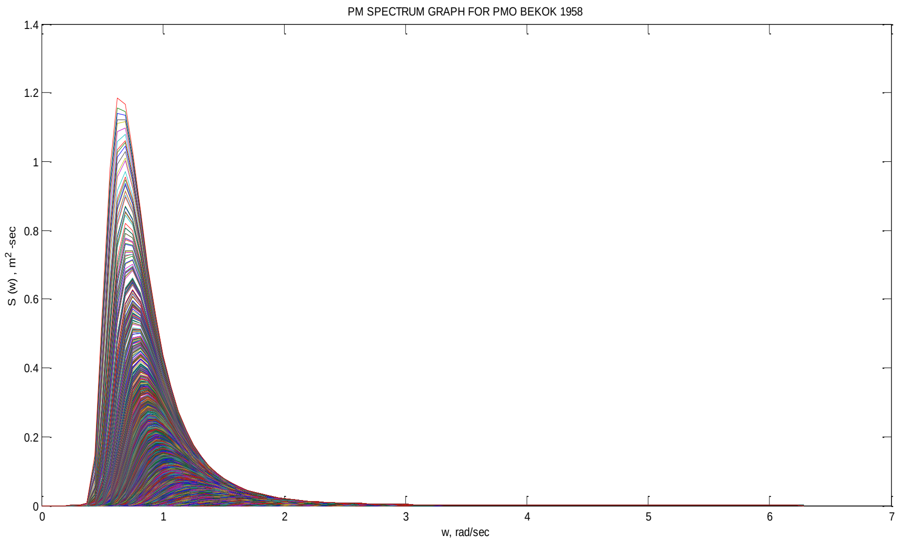


Figure 4.0: PM Spectrum Plot of a year of 1958 data in Bekok (PMO) region

Based on Chakrabarti's publication, the significant wave height, *Hs* can be derived from the total energy content of the wave spectrum in the spectral plot. This are related to the total area under the curve of the wave energy density spectrum, m_o. The derivation of m_o, was studied and proceed with computing Hs based on m_o analysis. the result of the calculated Hs are then being compared with the recorded Hindcast Metocean data for the specific wind speed parameter in term of polynomial graph and also ratio of both Hs data. In order to optimizing the amount of Hindcast MetOcean data that have been recorded over more than 50 years of such continuous data, the spectral plots are made by each 10 years gap for each region. In addition, the spectral plots are made and the computation of m_o be done for each region which leads to the findings of Hs. The envelope polynomial of Bekok region together with original recorded data are plotted in order to observing and producing comprehensive representation on the spectral behavior of the Malay Basins. The ratio of significant wave height with respect to its corresponding wind speed are then compared with the ratio of calculated significant wave height formulated from spectral plots. The sample graph plotted of significant wave height for each identified year are shown as follows:

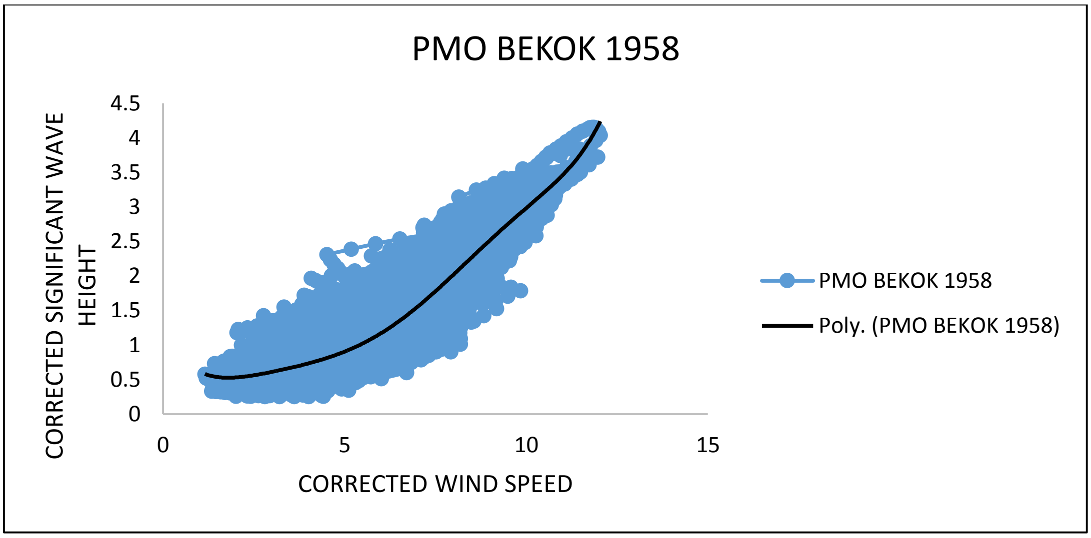


Figure 4.1: Hs Vs Ws for PMO BEKOK 1958

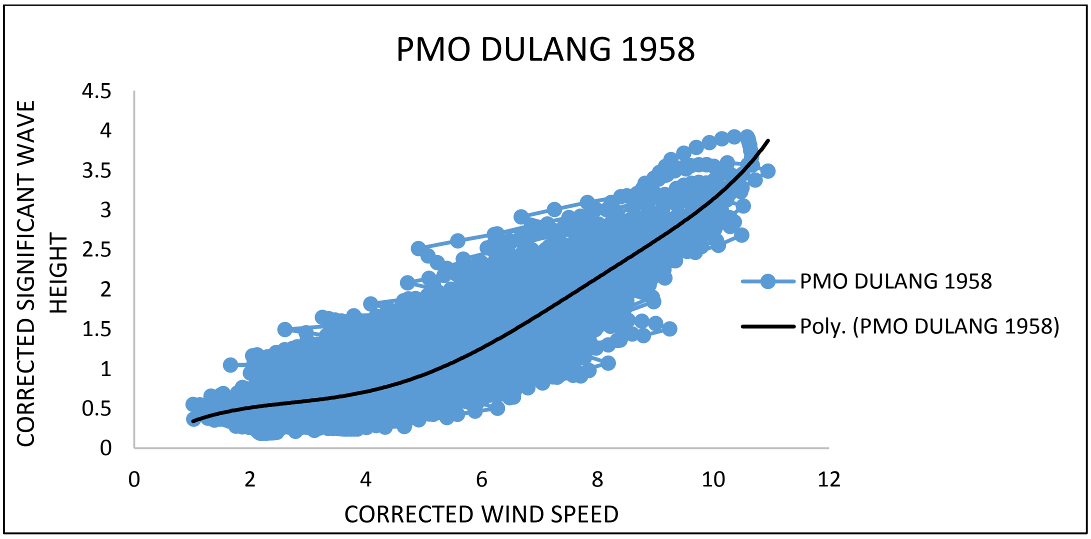


Figure 4.2: Hs Vs Ws for PMO DULANG 1958

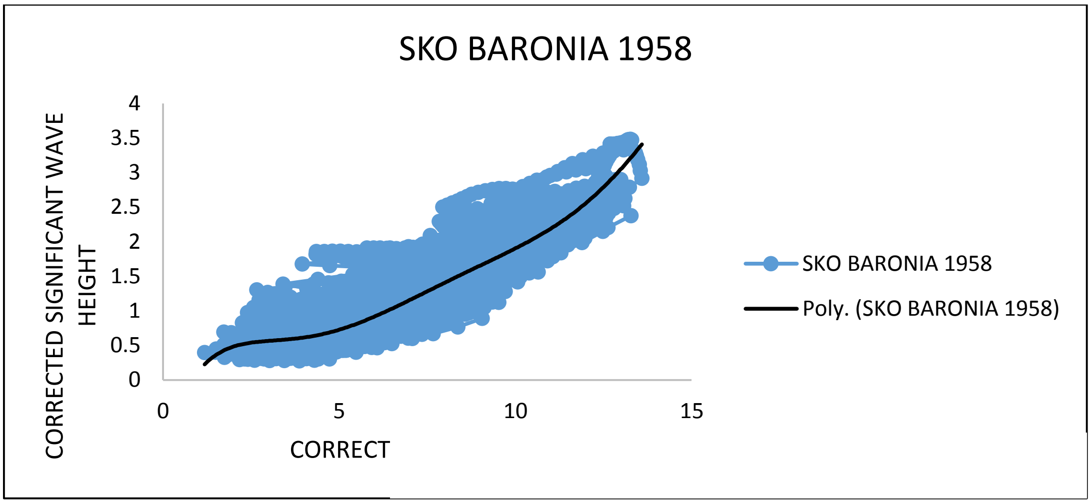


Figure 4.3: Hs Vs Ws for SKO BARONIA 1958

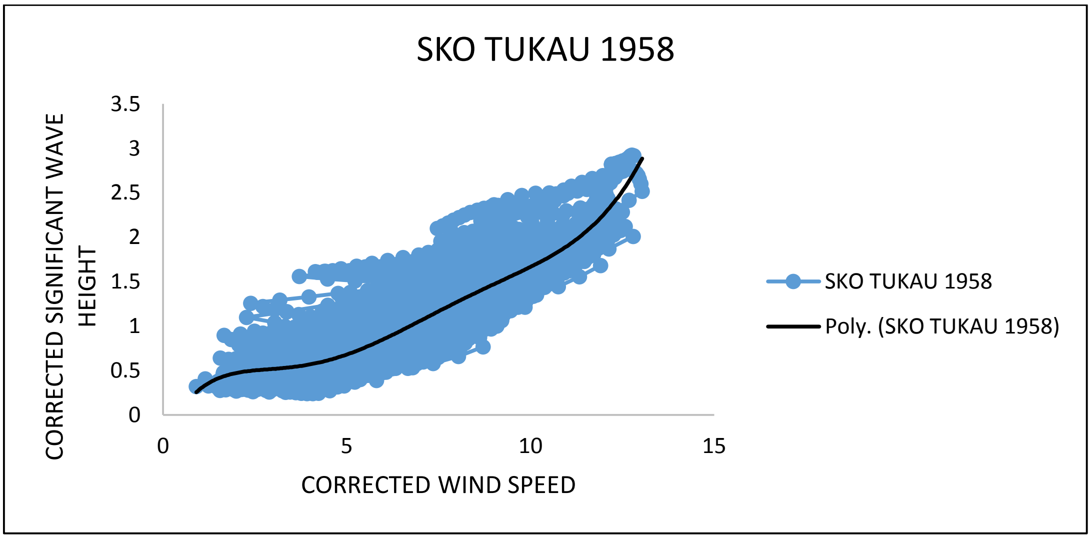


Figure 4.4: Hs Vs Ws for SKO TUKAU 1958

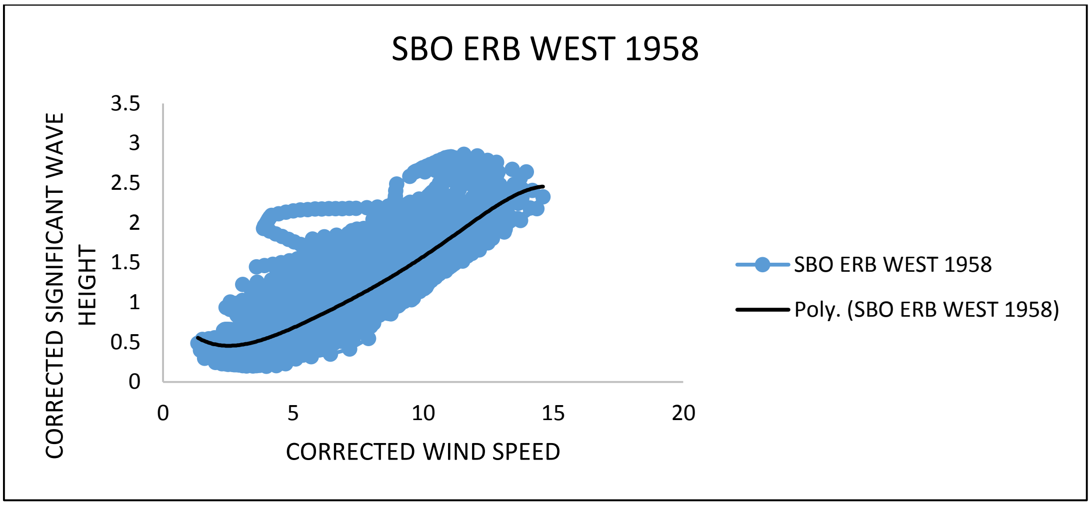


Figure 4.5: Hs Vs Ws for SBO ERB WEST 1958

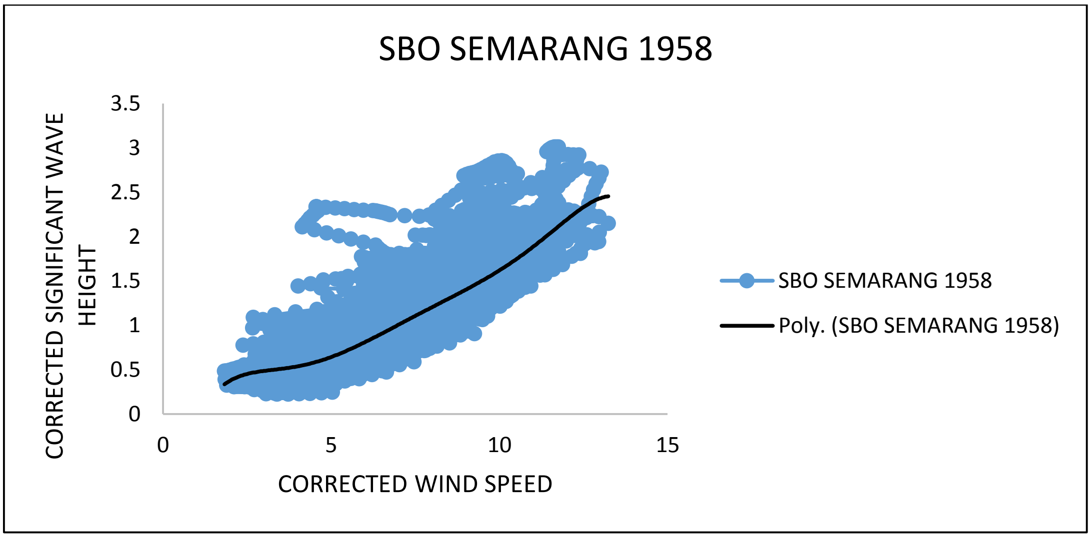


Figure 4.6: Hs Vs Ws for SBO SEMARANG 1958

Since the Hindcast MetOcean Data does not include the dominant wind speed direction, thus, wind rose plot are done in order to proceed with the JONSWAP Spectrum analysis and NALL Spectrum analysis. On the other hand, the ratio of the significant wave height with it respective wind speed are then compared for each spectrum together with the SEAFINE MetOcean data. Based on the ratio, NALL spectrum shows the lowest ration followed by JONSWAP Spectrum which both are refer to partially developed sea. Therefore, according to ratio analysis, Continental Shelf Malaysia could be conclude as partially developed sea.

PLATFORM	MEASURED DATA	PM SPECTRUM	JONSWAP SPECTRUM	NALL SPECTRUM
PMO BEKOK	WIND SPEED = 12.04			
	4.0368	3.092217238	0.068468985	0.000559058
	SIGNIFICANT WAVE HEIGHT			
	0.335282392	0.2568	0.0057	0.0000464
PMO DULANG	WIND SPEED = 10.9478			
	SIGNIFICANT WAVE HEIGHT			
	3.4908	2.55608201	1.796866715	0.13830729
	0.3189	0.2335	0.1641	0.0126
SKO BARONIA	WIND SPEED = 13.5845			
	SIGNIFICANT WAVE HEIGHT			
	2.91776	1.086680533	1.874954122	0.001359134
	0.2148	0.0800	0.1380	0.0001
SKO TUKAU	WIND SPEED = 13.0391			
	SIGNIFICANT WAVE HEIGHT			
	2.51715	3.626180087	1.845043738	0.001337633
	0.1930	0.2781	0.1415	0.0001
SBO ERB WEST	WIND SPEED = 14.602			
	SIGNIFICANT WAVE HEIGHT			
	2.32575	4.547687779	1.268689672	0.000920012
	0.1593	0.3114	0.0869	0.0001
SBO SEMARANG	WIND SPEED = 13.2398			
	SIGNIFICANT WAVE HEIGHT			
	2.1483	3.738688877	1.71942261	0.001246996
	0.1623	0.2824	0.1299	0.0001

Table 4.0: Ratio of significant wave height to wind speed for 1958

PLATFORM	MEASURED DATA	PM SPECTRUM	JONSWAP SPECTRUM	NALL SPECTRUM
PMO BEKOK	**WIND SPEED = 11.5068**			
	SIGNIFICANT WAVE HEIGHT			
	2.8788	2.823884231	1.820192235	0.001539857
	0.250182501	0.245410039	0.158184051	0.000133821
PMO DULANG	**WIND SPEED = 10.7156**			
	SIGNIFICANT WAVE HEIGHT			
	2.604	2.448770842	1.745606685	0.001477267
	0.2430	0.2285	0.1629	0.0001
SKO BARONIA	**WIND SPEED = 13.3421**			
	SIGNIFICANT WAVE HEIGHT			
	2.58505	3.796698174	1.851951909	0.001342581
	0.1938	0.2846	0.1388	0.0001
SKO TUKAU	**WIND SPEED = 12.8472**			
	SIGNIFICANT WAVE HEIGHT			
	2.03215	3.52022589	1.826250697	0.001324202
	0.1582	0.2740	0.1422	0.0001
SBO ERB WEST	**WIND SPEED = 14.6412**			
	SIGNIFICANT WAVE HEIGHT			
	2.14935	4.572137261	1.271018158	0.000921694
	0.1468	0.3123	0.0868	0.0001
SBO SEMARANG	**WIND SPEED = 13.5828**			
	SIGNIFICANT WAVE HEIGHT			
	2.0076	3.93494894	1.366886644	0.000991074
	0.1478	0.2897	0.1006	0.0001

Table 4.1: Ratio of significant wave height to wind speed for 1968

PLATFORM	MEASURED DATA	PM SPECTRUM	JONSWAP SPECTRUM	NALL SPECTRUM
PMO BEKOK	**WIND SPEED = 11.4122**			
	SIGNIFICANT WAVE HEIGHT			
	3.5256	2.512085099	1.966180557	0.001426347
	0.308932546	0.220122772	0.172287601	0.000124984
PMO DULANG	**WIND SPEED = 10.8532**			
	SIGNIFICANT WAVE HEIGHT			
	3.3168	2.512085099	1.760807145	0.001277274
	0.3056	0.2315	0.1622	0.0001
SKO BARONIA	**WIND SPEED = 13.6552**			
	SIGNIFICANT WAVE HEIGHT			
	3.18742	3.97701668	1.881597481	0.001363945
	0.2334	0.2912	0.1378	0.0001
SKO TUKAU	**WIND SPEED = 13.1199**			
	SIGNIFICANT WAVE HEIGHT			
	2.67623	3.671268248	1.852911256	0.001343269
	0.2040	0.2798	0.1412	0.0001
SBO ERB WEST	**WIND SPEED = 14.694**			
	SIGNIFICANT WAVE HEIGHT			
	3.20178	0.415604806	1.274151807	0.000923957
	0.2179	0.0883	0.0267	0.0001
SBO SEMARANG	**WIND SPEED = 12.8184**			
	SIGNIFICANT WAVE HEIGHT			
	2.8266	3.504445482	1.314169564	0.000952733
	0.2205	0.2734	0.1025	0.0001

Table 4.2: Ratio of significant wave height to wind speed for 1978

CHAPTER 5

CONCLUSION AND RECOMMENDATION

Based on the results and discussion gathered, the spectral plot for Continental Shelf Malaysia is developed and plotted with comparison to other available spectrums. Besides, from the plotted wind rose diagram for all case study in 6 different platform, it can be said that there is actually no different of dominant wind direction since all the results shows significantly similar direction which is towards Northeast direction. From the plotted graph of 6 different locations, it shows that there are a positive correlation between wind speed and wave height. But, further study and deeper analysis should be done by involving more data in order to make correct analysis about previous assumption regarding the seasonal affect. In the process, the significant wave height and wind speed of the regions studied in Continental Shelf Malaysia is obtained, whereby a reginal difference was found from the location studied at PMO, SKO and SBO respectively to the parameters studied.

However, it can be concluded that the study of correlation between wind speed and wave height together with analysis about sea development in Continental Shelf Malaysia could be done in this study period. Moreover, further study involving another location at Continental Shelf Malaysia by considering the whole of Malay Basins also need to be done in order to make a comparison of the finding. Besides, since this study involved only in one specific field of platform, thus further study could be considering more critical field such as Miri field, Bintulu field and many more whereby can compare with the current finding.

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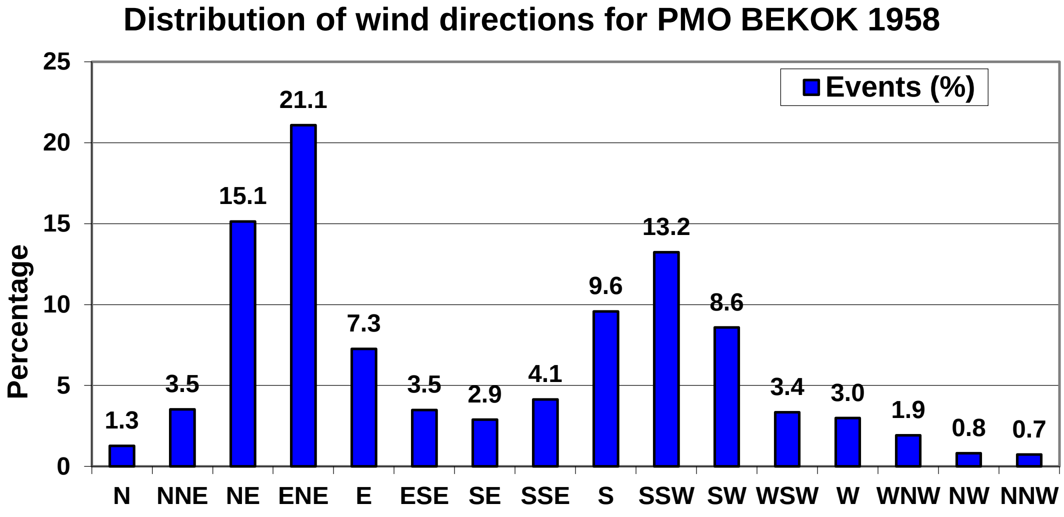
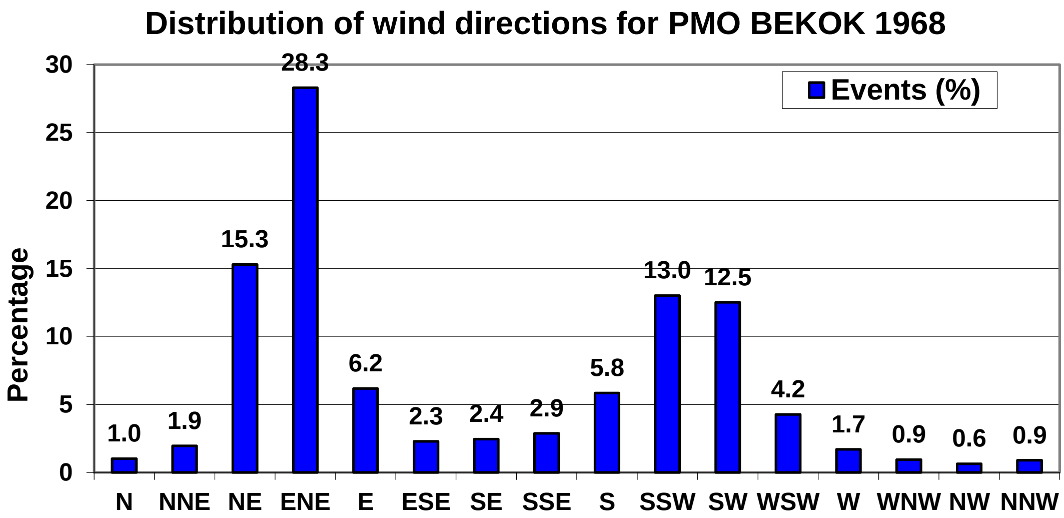
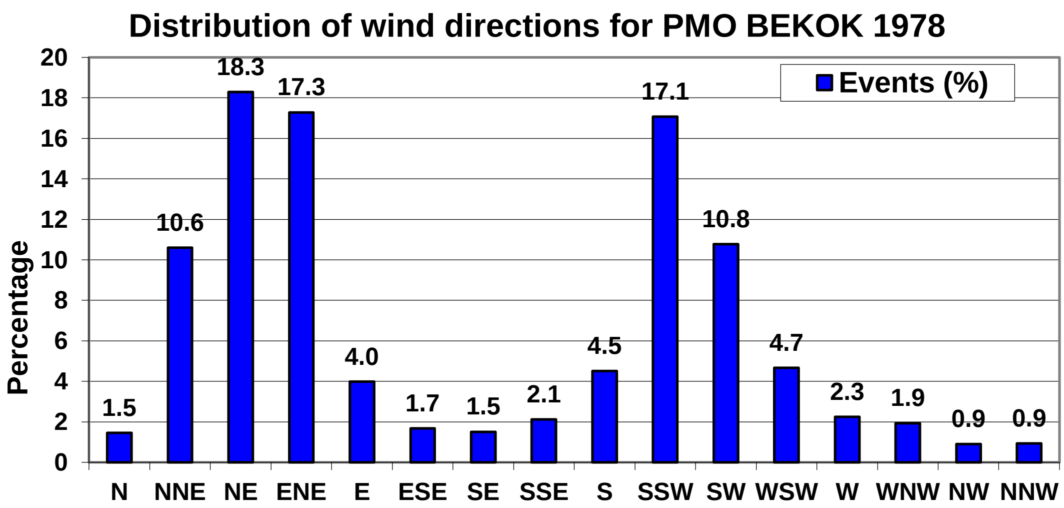
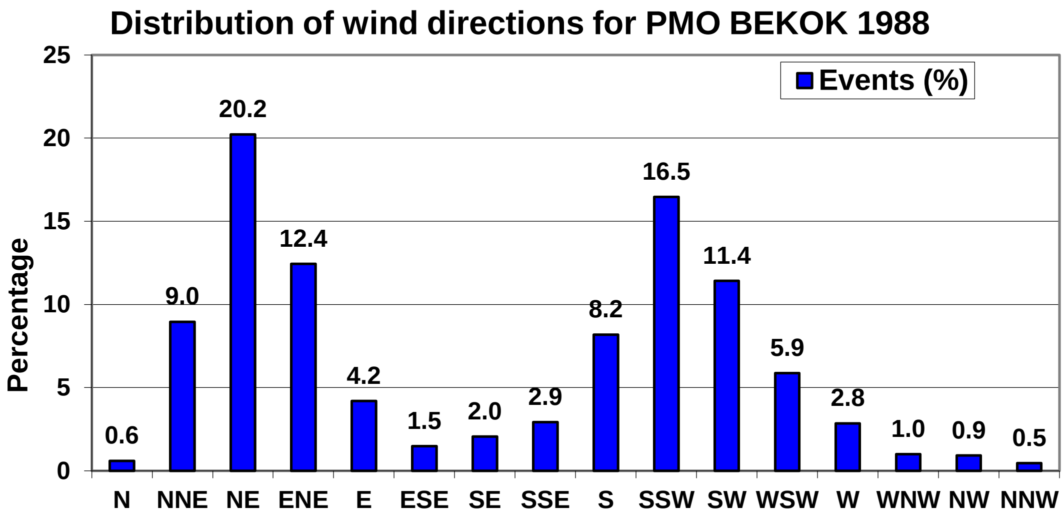
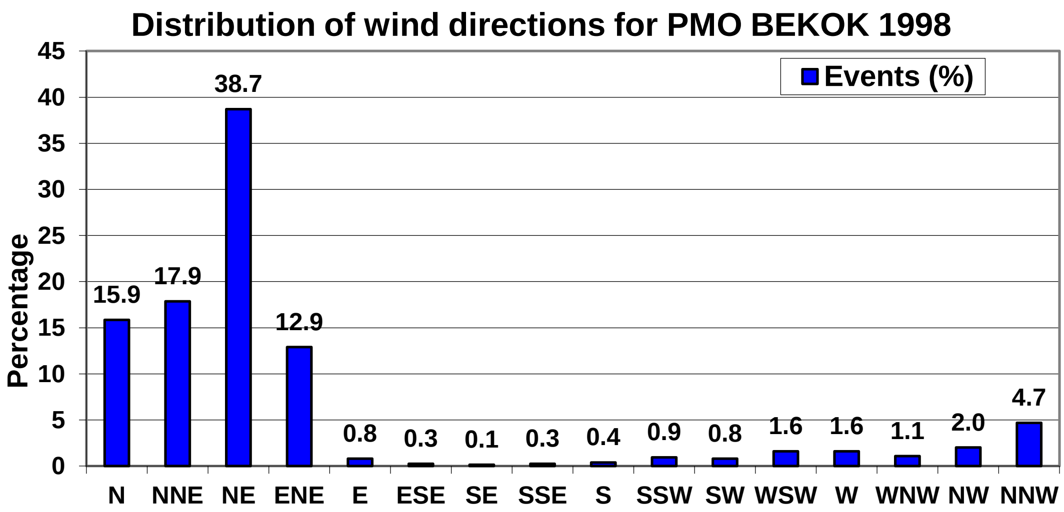
I. WIND DIRECTION DISTRIBUTION (PMO BEKOK 1958, 1968, 1978, 1988 and 1998)











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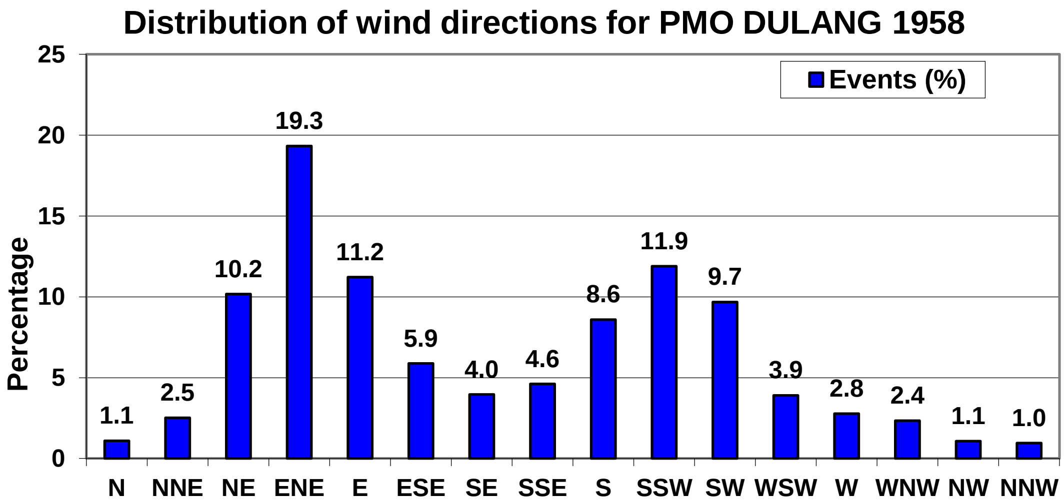
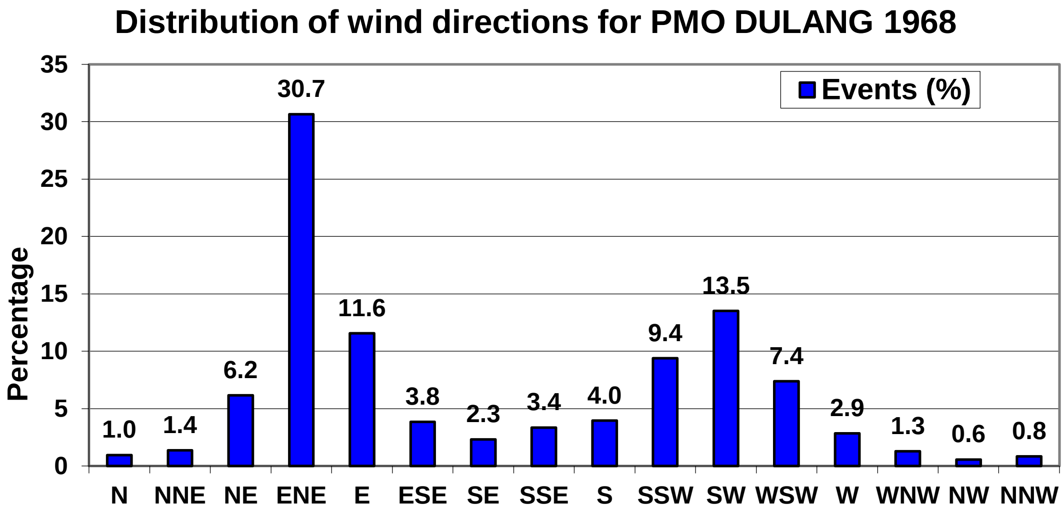
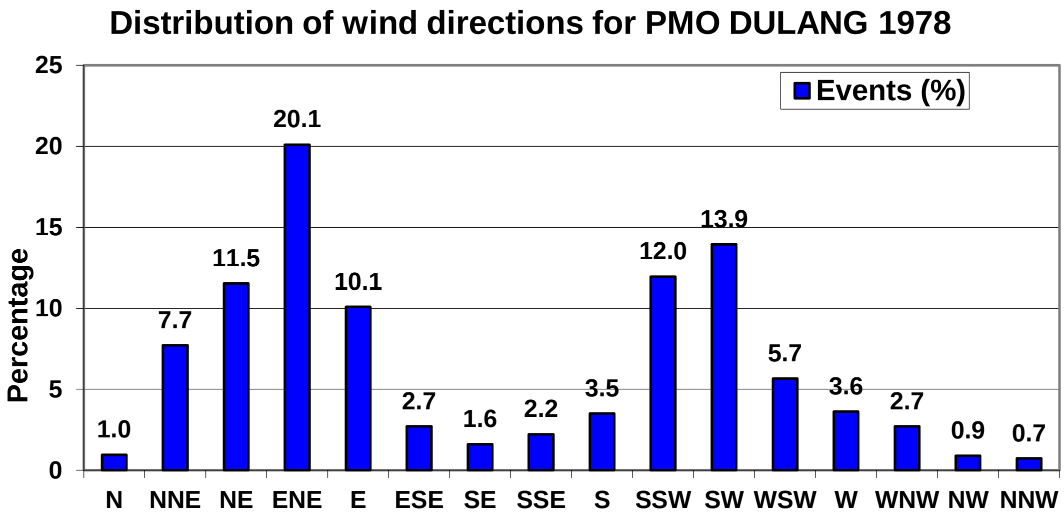
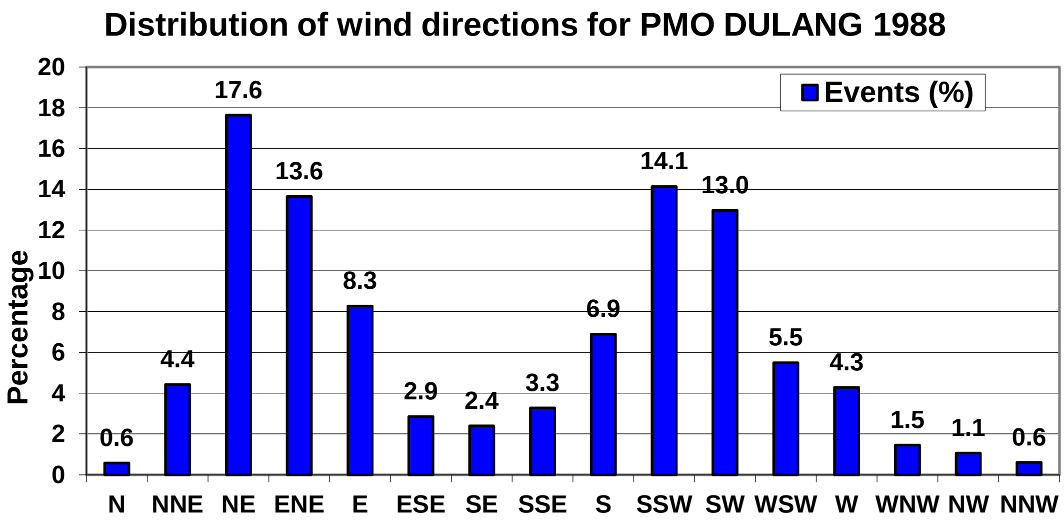




Distribution of wind directions for PMO DULANG 1968
Events (%)
Percentage
35
30
25
20
15
10
5
0
30.7
11.6
13.5
9.4
7.4
6.2
3.8
2.3
3.4
4.0
2.9
1.0
1.4
1.3
0.6
0.8
N NNE NE ENE E ESE SE SSE S SSW SW WSW W WNW NW NNW

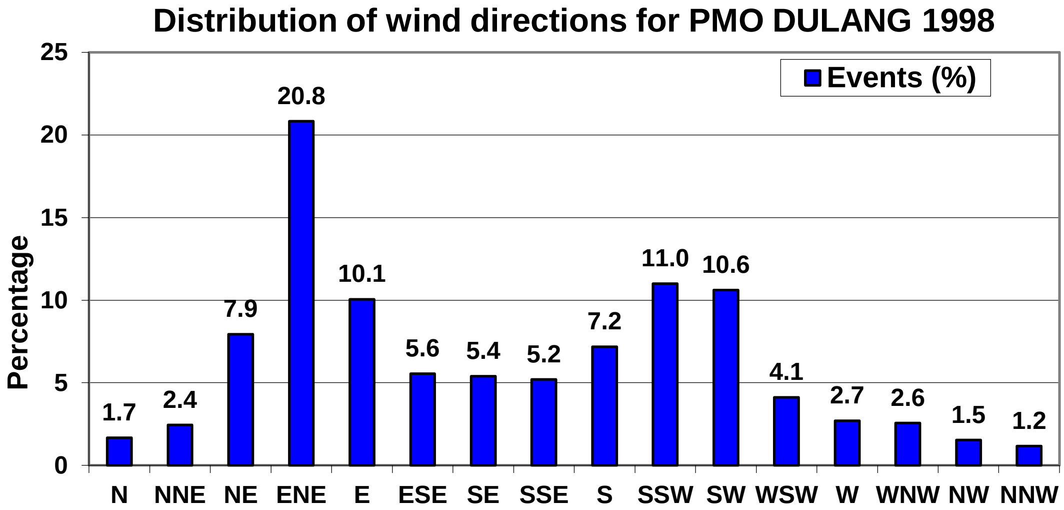


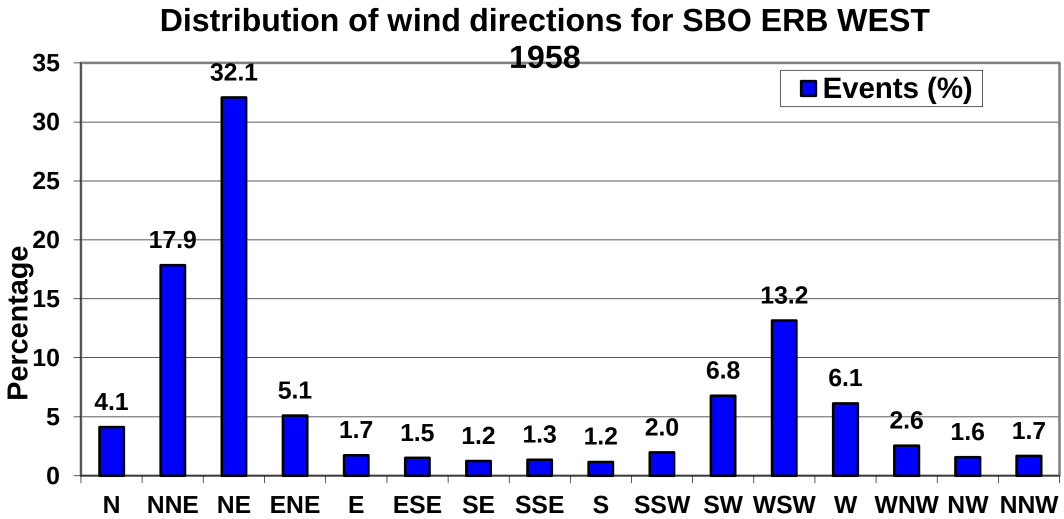
Distribution of wind directions for PMO DULANG 1978
Events (%)
Percentage
25
20
15
10
5
0
20.1
13.9
12.0
11.5
10.1
7.7
5.7
3.6
3.5
2.7
2.7
2.2
1.6
1.0
0.9
0.7
N NNE NE ENE E ESE SE SSE S SSW SW WSW W WNW NW NNW

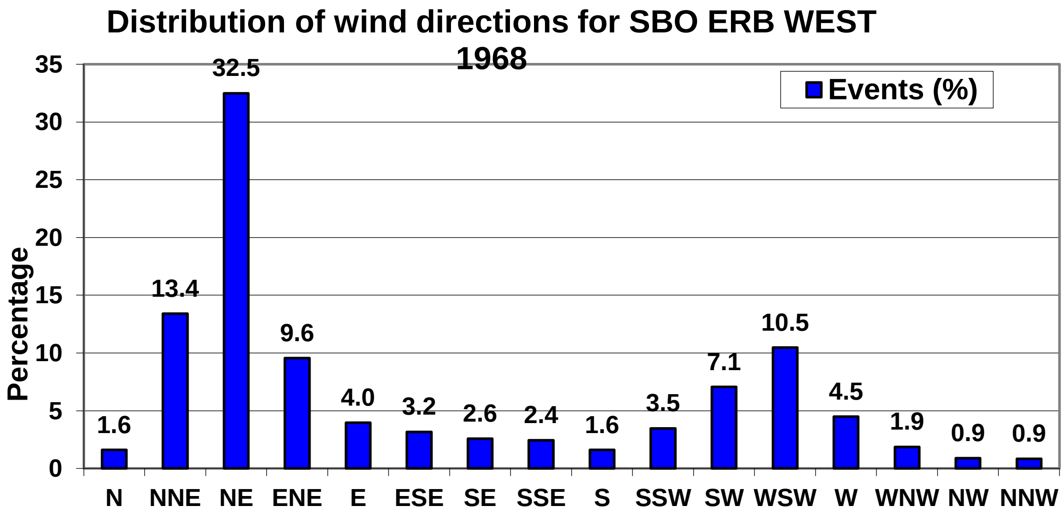


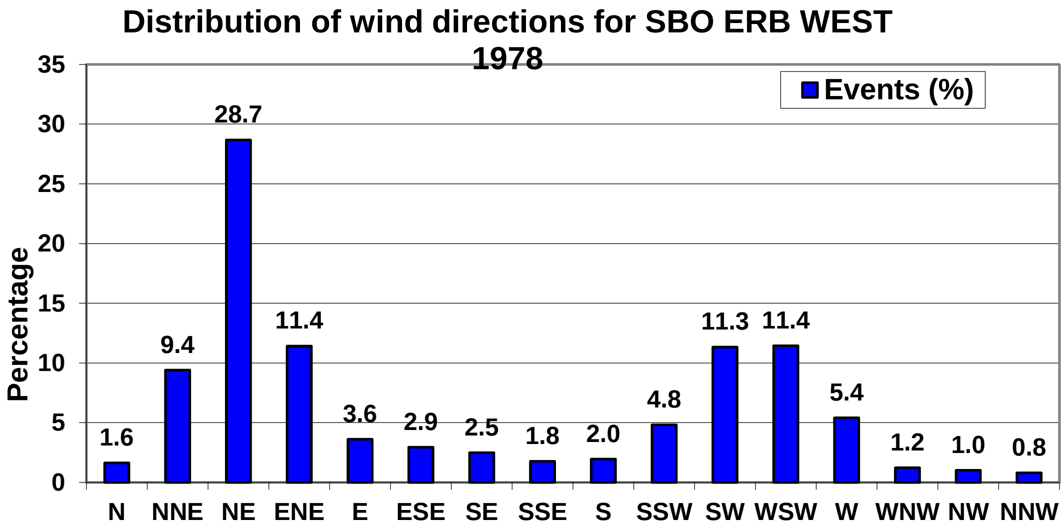
Distribution of wind directions for PMO DULANG 1988
Events (%)
Percentage
20
18
16
14
12
10
8
6
4
2
0
17.6
13.6
14.1
13.0
8.3
6.9
5.5
4.4
4.3
3.3
2.9
2.4
1.5
1.1
0.6
0.6
N NNE NE ENE E ESE SE SSE S SSW SW WSW W WNW NW NNW

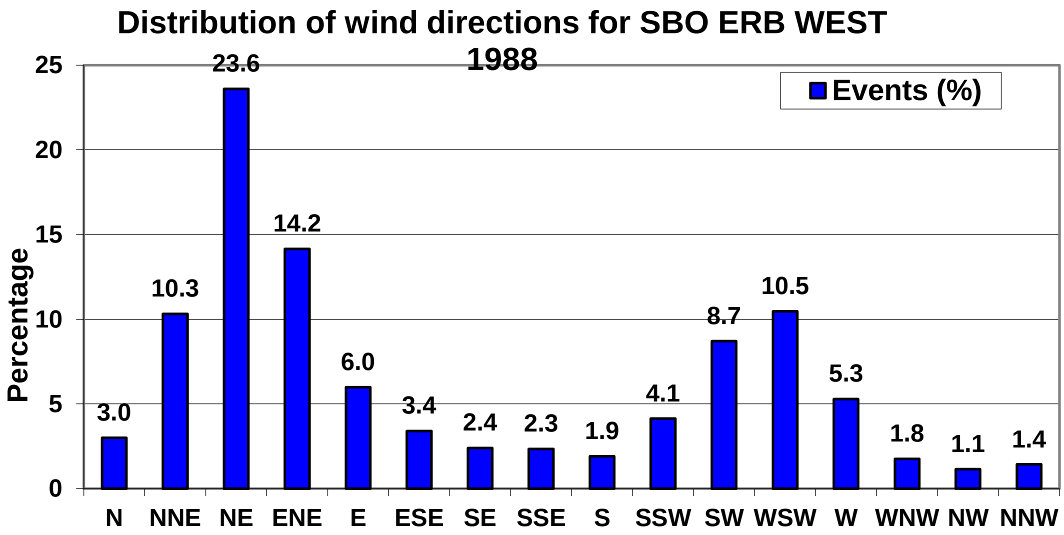
III. WIND DIRECTION DISTRIBUTION (SBO ERB WEST 1958, 1968, 1978, 1988 and 1998)

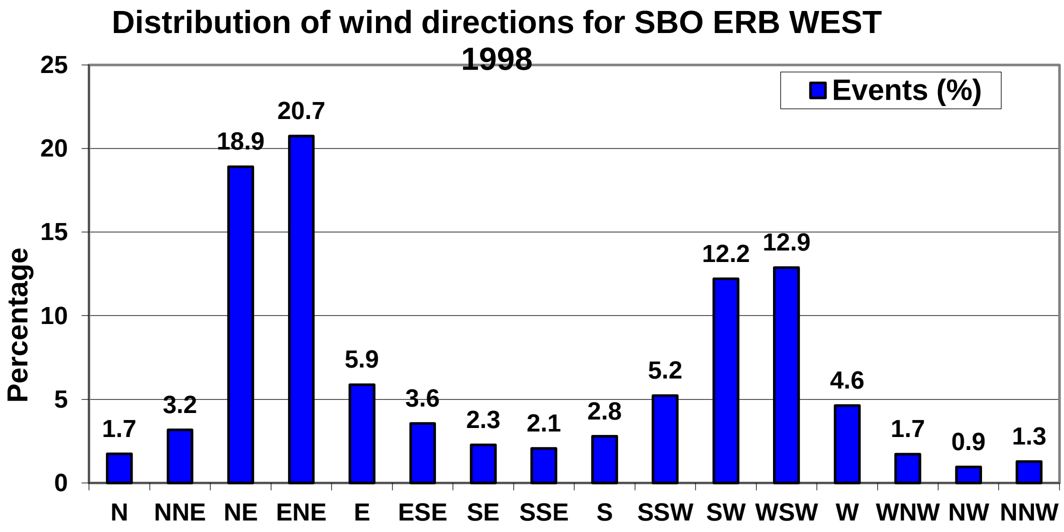




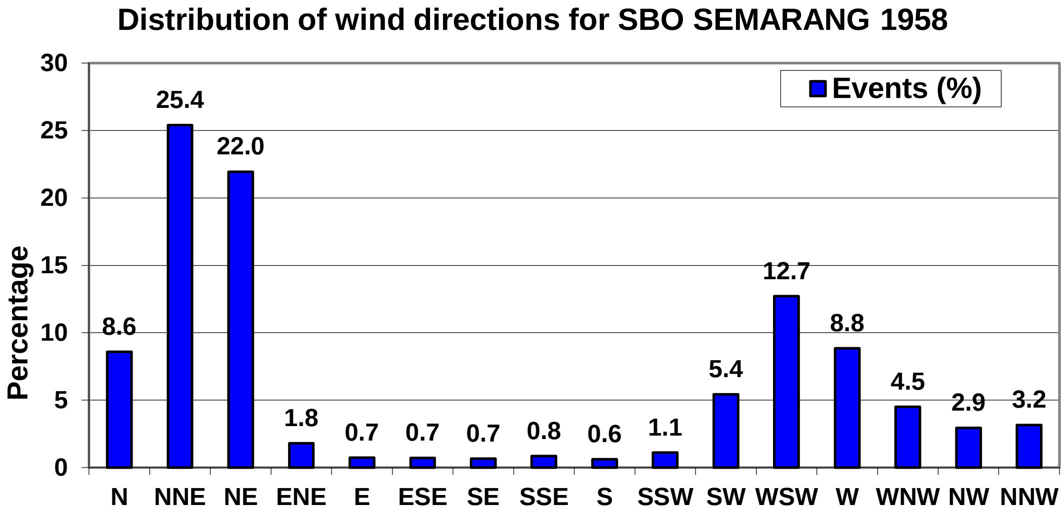


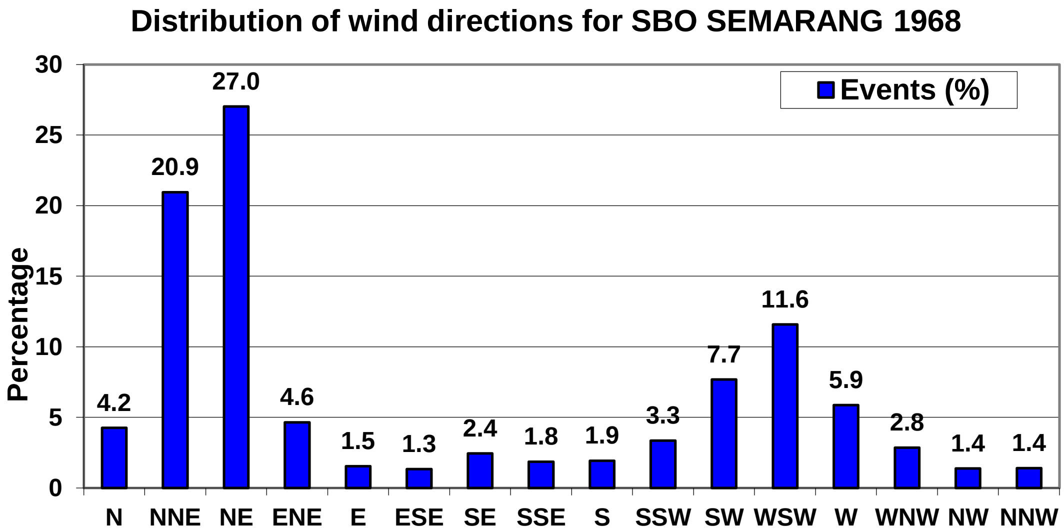

Distribution of wind directions for SBO ERB WEST 1978
Events (%)
Percentage
35
30
25
20
15
10
5
0
28.7
9.4
11.4
1.6
3.6
2.9
2.5
1.8
2.0
4.8
11.3
11.4
5.4
1.2
1.0
0.8
N NNE NE ENE E ESE SE SSE S SSW SW WSW W WNW NW NNW

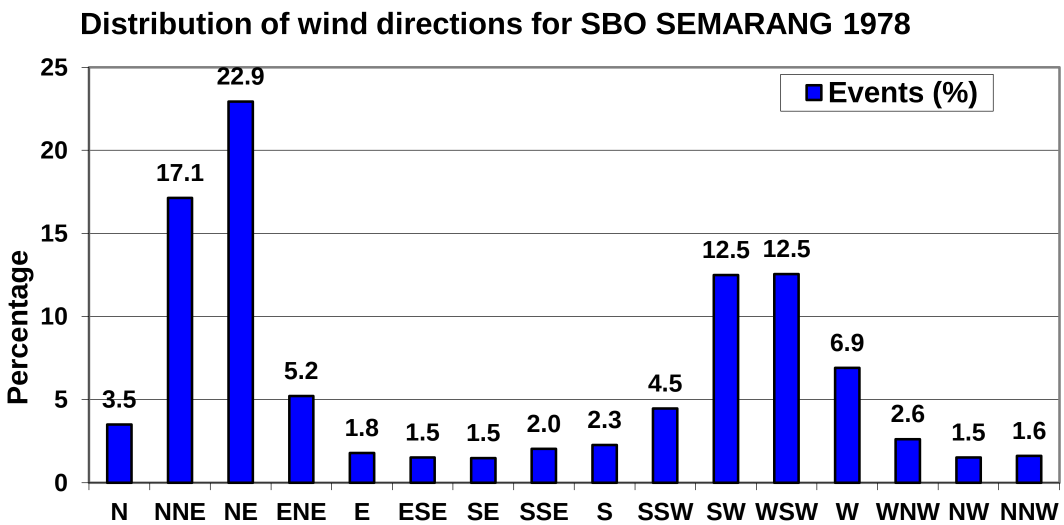

Distribution of wind directions for SBO ERB WEST 1988
Events (%)
Percentage
25
20
15
10
5
0
3.0
10.3
23.6
14.2
6.0
3.4
2.4
2.3
1.9
4.1
8.7
10.5
5.3
1.8
1.1
1.4
N NNE NE ENE E ESE SE SSE S SSW SW WSW W WNW NW NNW

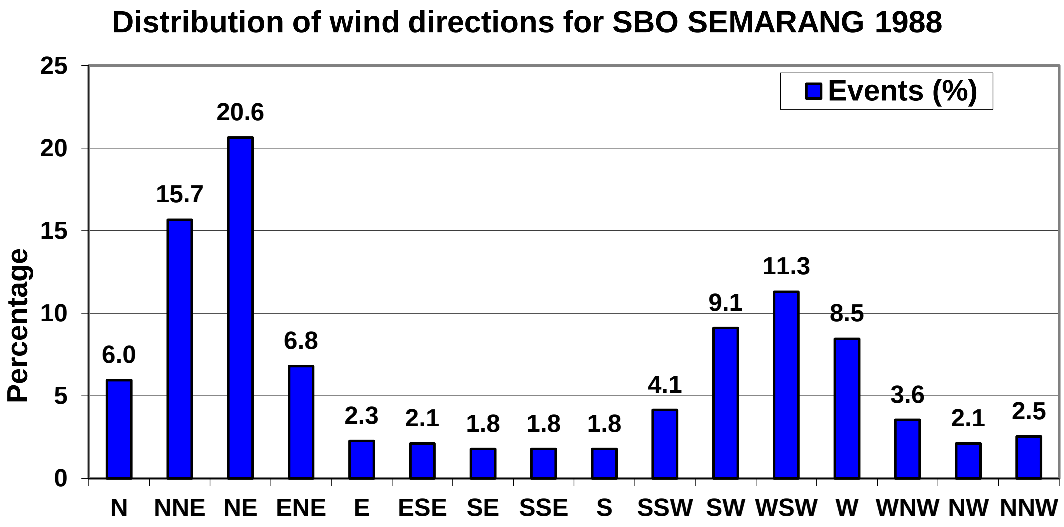

Distribution of wind directions for SBO ERB WEST 1998
Events (%)
Percentage
25
20
15
10
5
0
1.7
3.2
18.9
20.7
5.9
3.6
2.3
2.1
2.8
5.2
12.2
12.9
4.6
1.7
0.9
1.3
N NNE NE ENE E ESE SE SSE S SSW SW WSW W WNW NW NNW

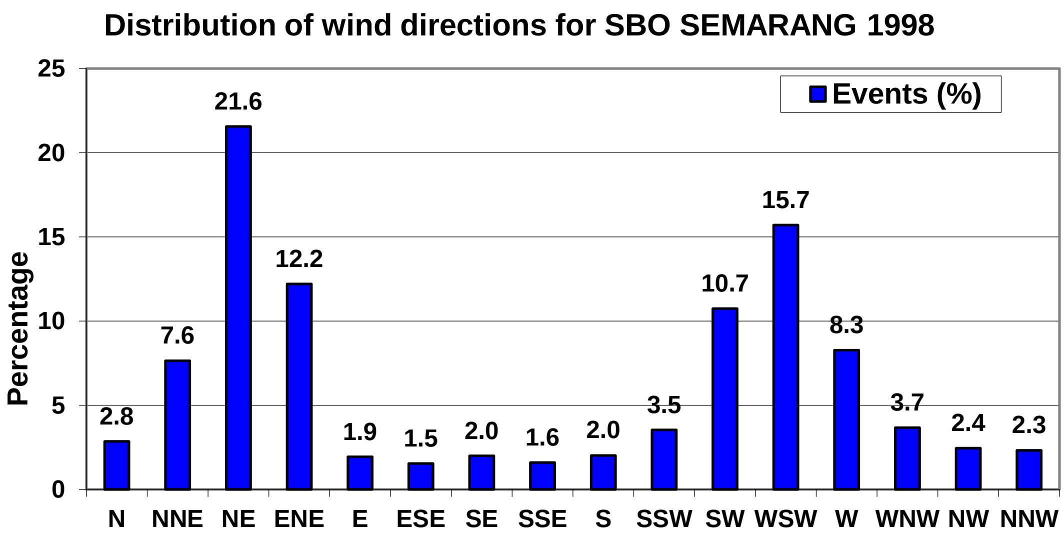
IV. WIND DIRECTION DISTRIBUTION (SBO SEMARANG 1958, 1968, 1978, 1988 and 1998)



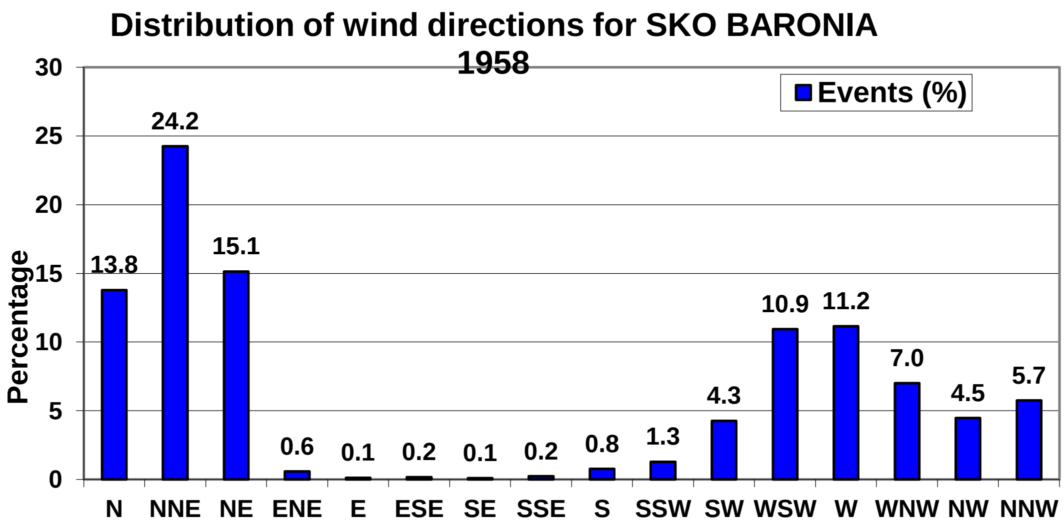


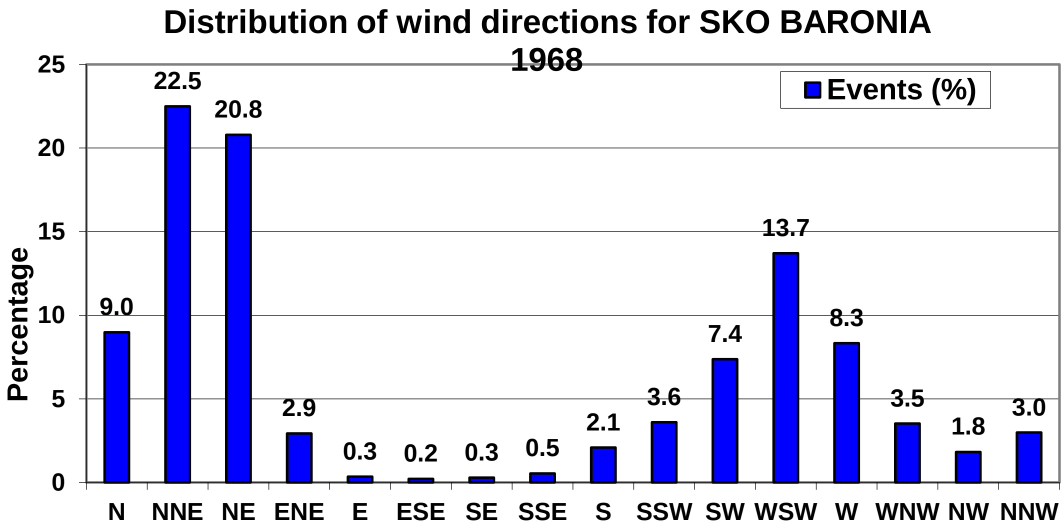




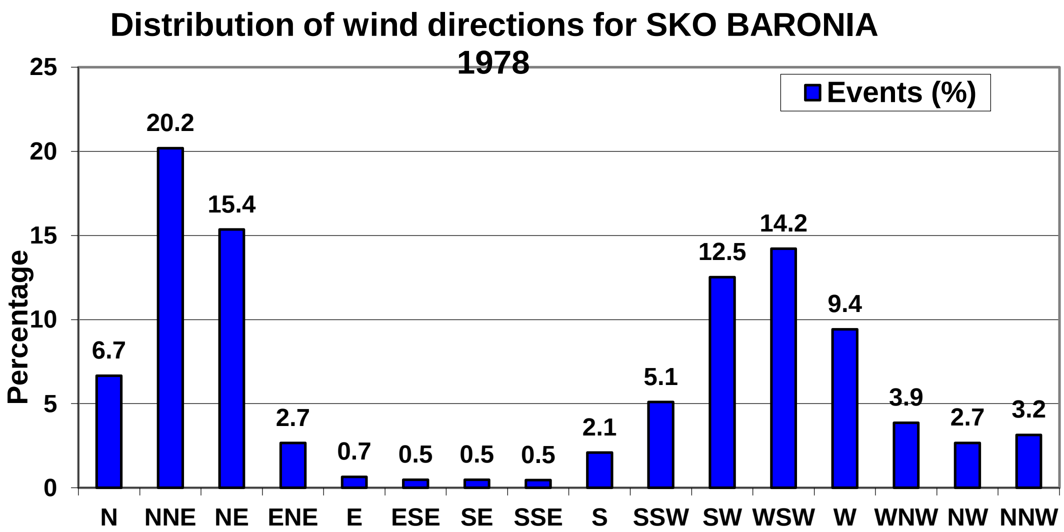


V. WIND DIRECTION DISTRIBUTION (SKO BARONIA 1958, 1968, 1978, 1988 and 1998)

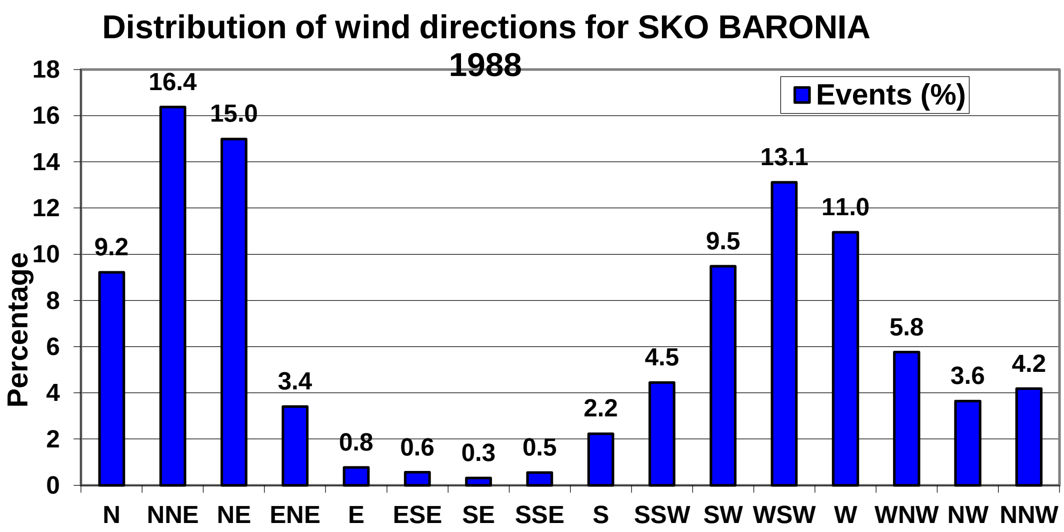




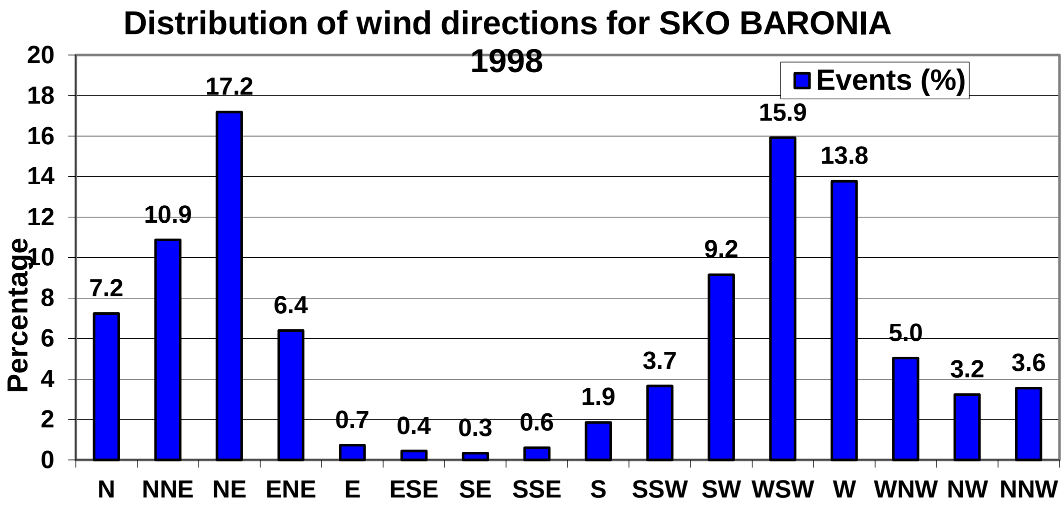
Distribution of wind directions for SKO BARONIA 1968
Events (%)
Percentage
25
20
15
10
5
0
9.0
22.5
20.8
2.9
0.3
0.2
0.3
0.5
2.1
3.6
7.4
13.7
8.3
3.5
1.8
3.0
N NNE NE ENE E ESE SE SSE S SSW SW WSW W WNW NW NNW



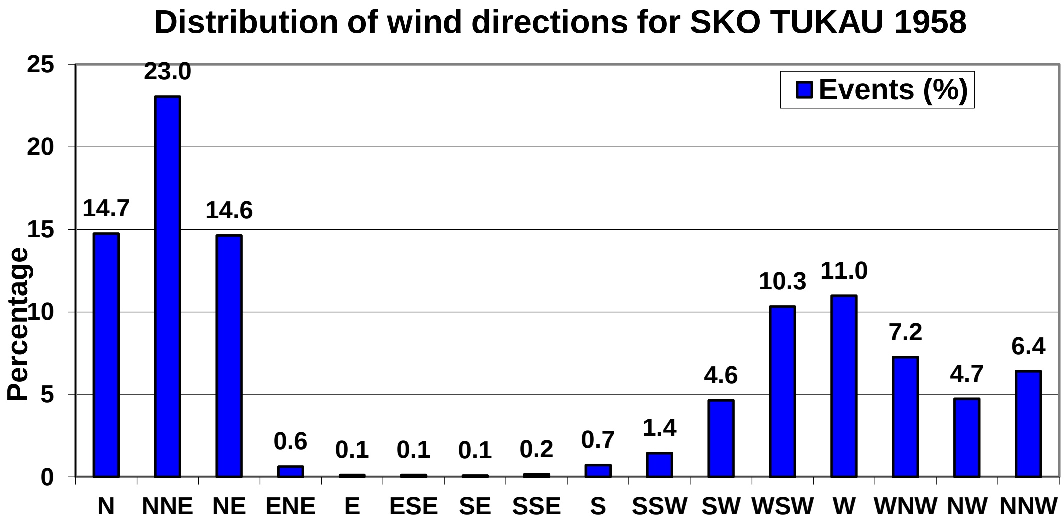
Distribution of wind directions for SKO BARONIA 1978
Events (%)
Percentage
25
20
15
10
5
0
6.7
20.2
15.4
2.7
0.7
0.5
0.5
0.5
2.1
5.1
12.5
14.2
9.4
3.9
2.7
3.2
N NNE NE ENE E ESE SE SSE S SSW SW WSW W WNW NW NNW

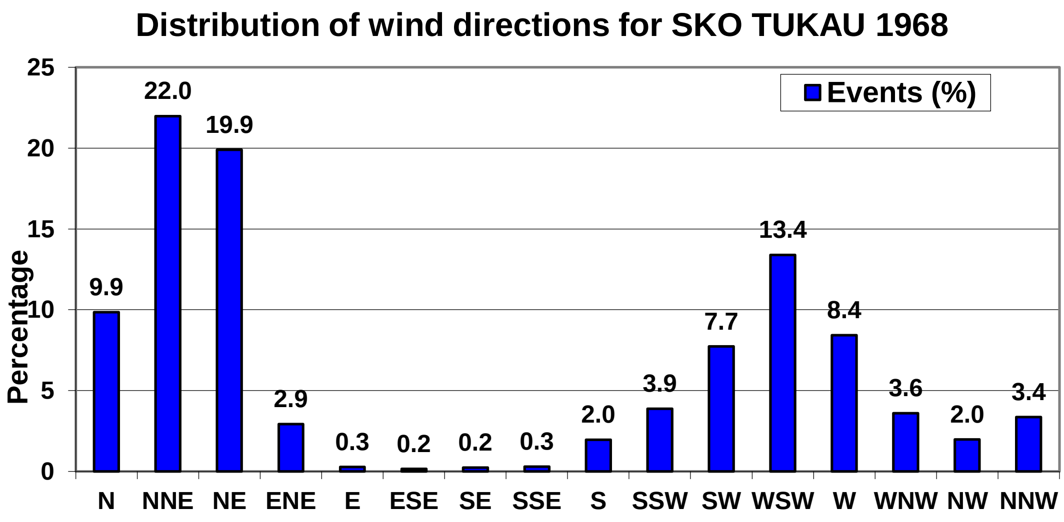


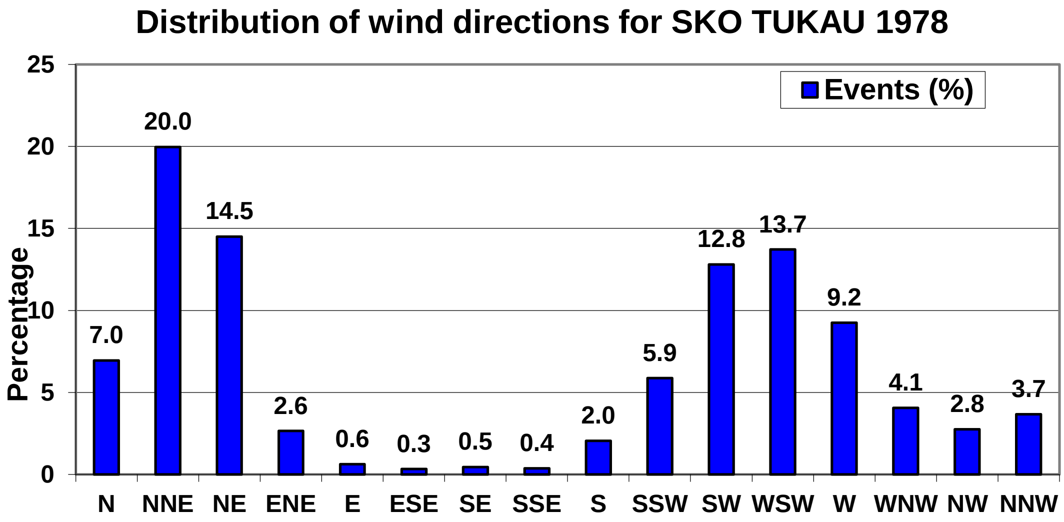
Distribution of wind directions for SKO BARONIA 1988
Events (%)
Percentage
18
16
14
12
10
8
6
4
2
0
9.2
16.4
15.0
3.4
0.8
0.6
0.3
0.5
2.2
4.5
9.5
13.1
11.0
5.8
3.6
4.2
N NNE NE ENE E ESE SE SSE S SSW SW WSW W WNW NW NNW

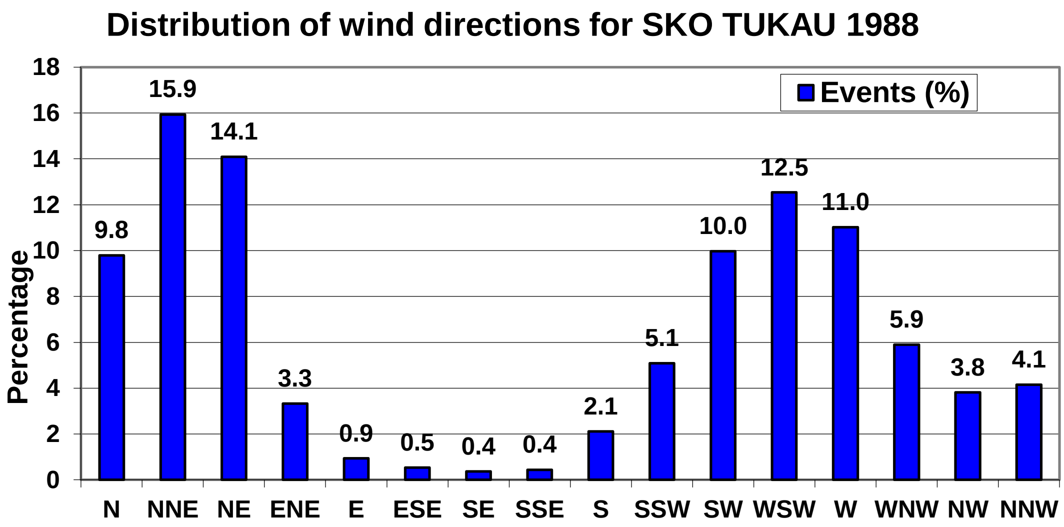


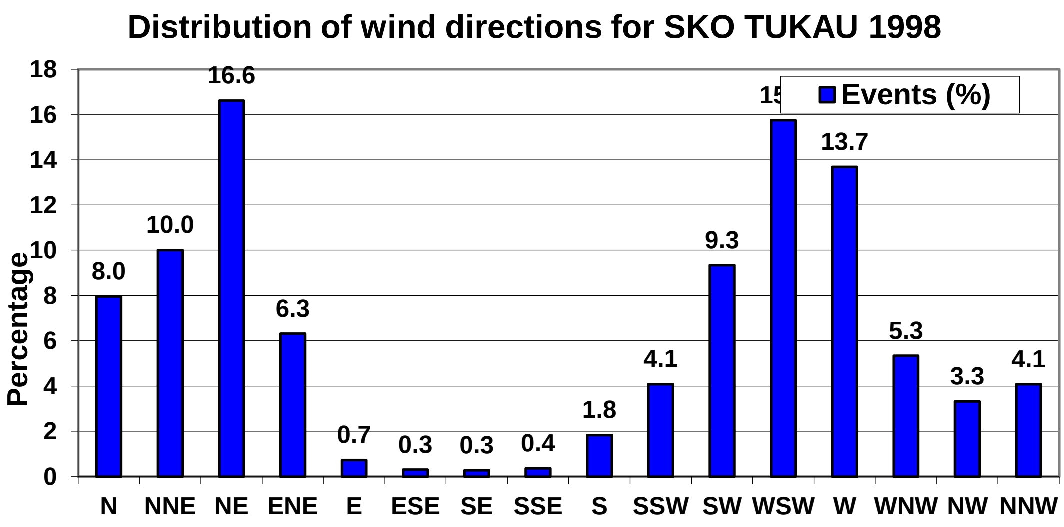
VI. WIND DIRECTION DISTRIBUTION (SKO TUKAU 1958, 1968, 1978, 1988 and 1998)



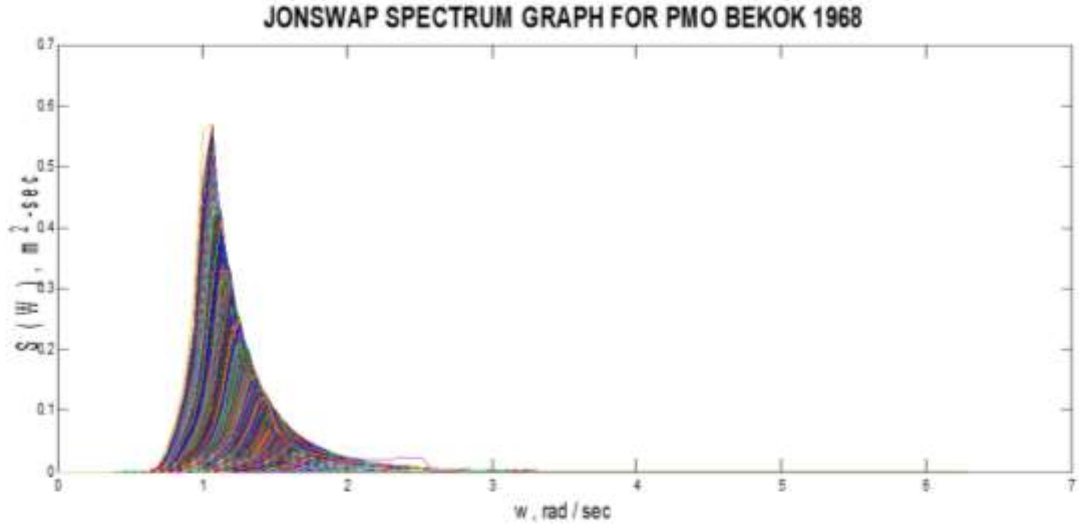


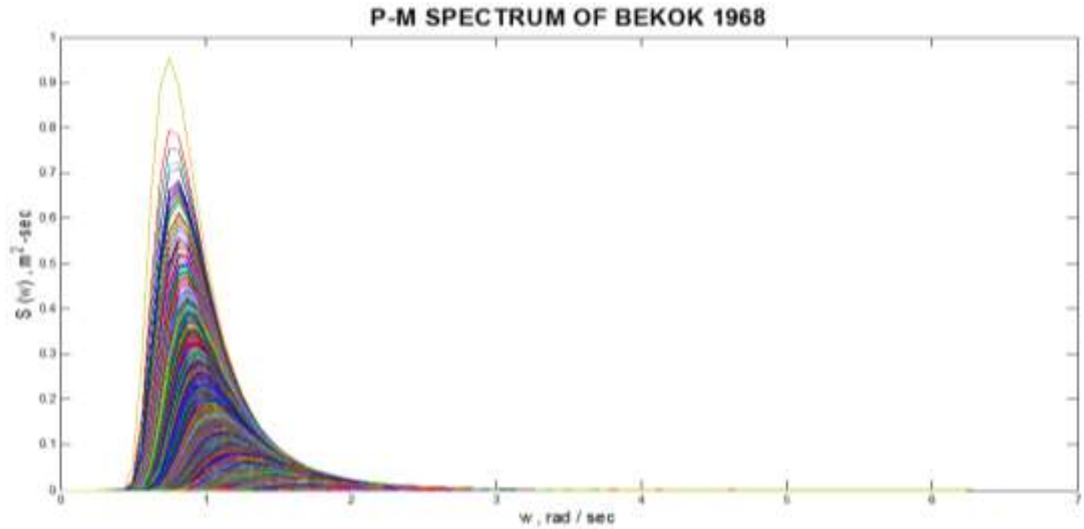

Distribution of wind directions for SKO TUKAU 1978
Events (%)
Percentage
0
5
10
15
20
25
7.0
20.0
14.5
2.6
0.6
0.3
0.5
0.4
2.0
5.9
12.8
13.7
9.2
4.1
2.8
3.7
N NNE NE ENE E ESE SE SSE S SSW SW WSW W WNW NW NNW

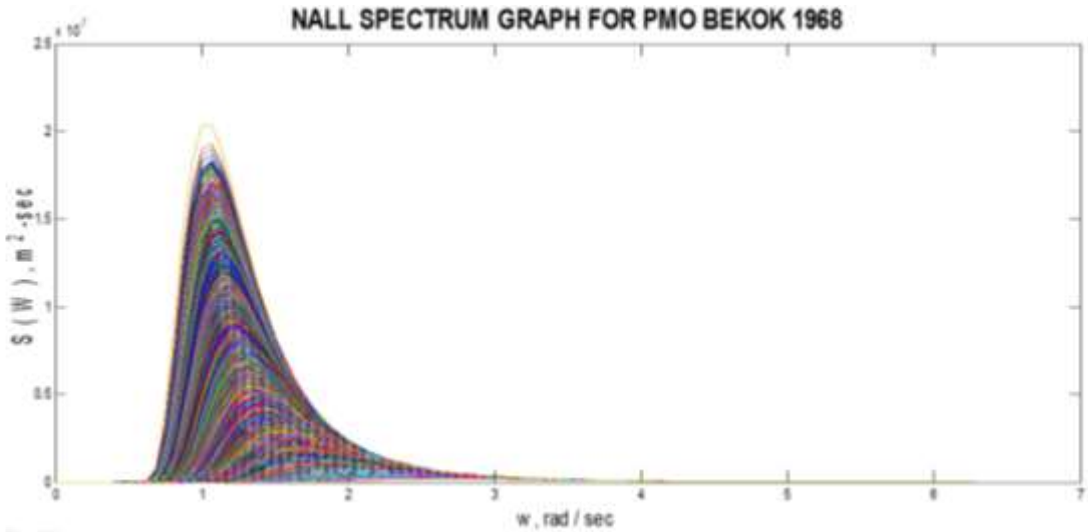

Distribution of wind directions for SKO TUKAU 1988
Events (%)
Percentage
0
2
4
6
8
10
12
14
16
18
9.8
15.9
14.1
3.3
0.9
0.5
0.4
0.4
2.1
5.1
10.0
12.5
11.0
5.9
3.8
4.1
N NNE NE ENE E ESE SE SSE S SSW SW WSW W WNW NW NNW


Distribution of wind directions for SKO TUKAU 1998
Events (%)
Percentage
0
2
4
6
8
10
12
14
16
18
8.0
10.0
16.6
6.3
0.7
0.3
0.3
0.4
1.8
4.1
9.3
15
13.7
5.3
3.3
4.1
N NNE NE ENE E ESE SE SSE S SSW SW WSW W WNW NW NNW

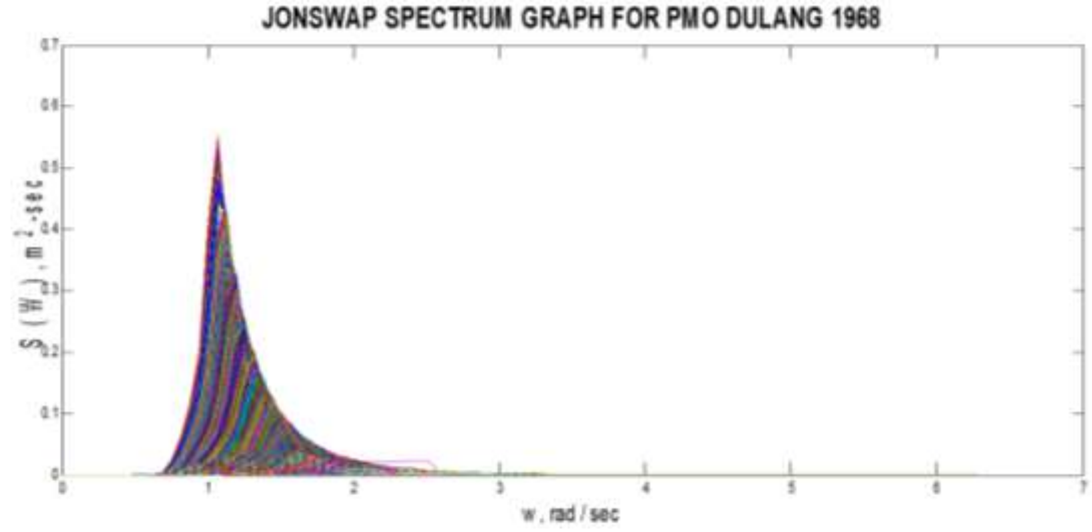
I. WAVE ENERGY SPECTRUM (PMO BEKOK 1968)

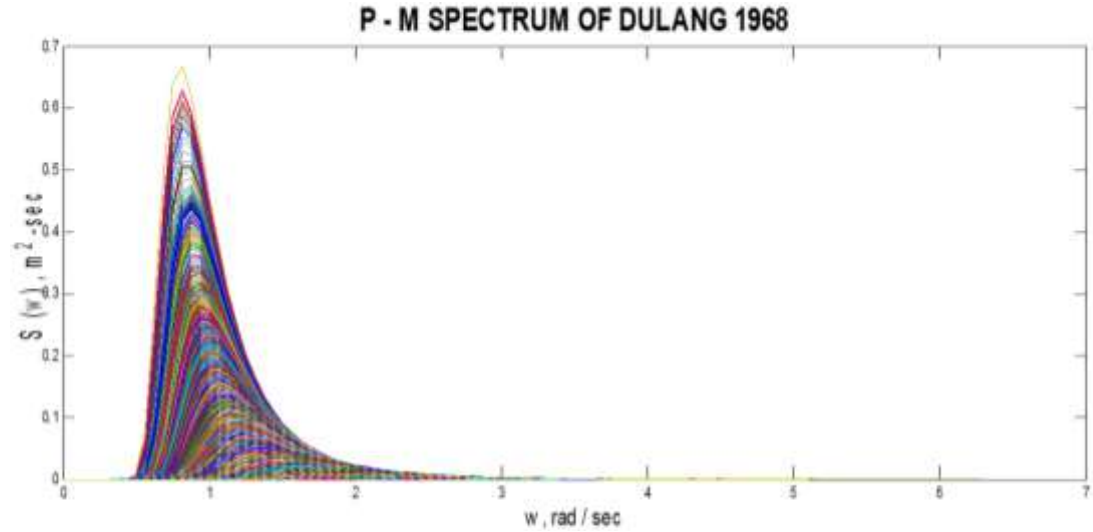


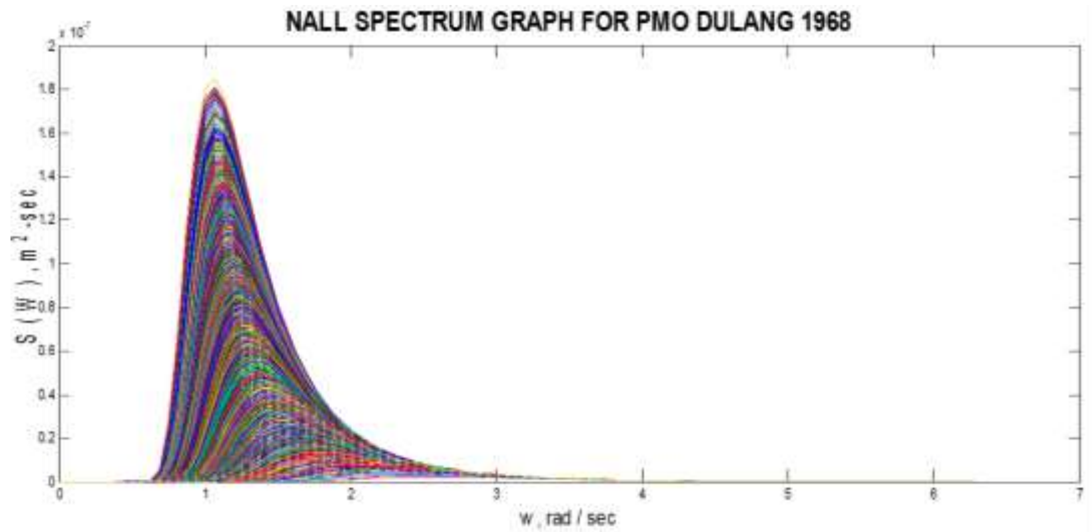




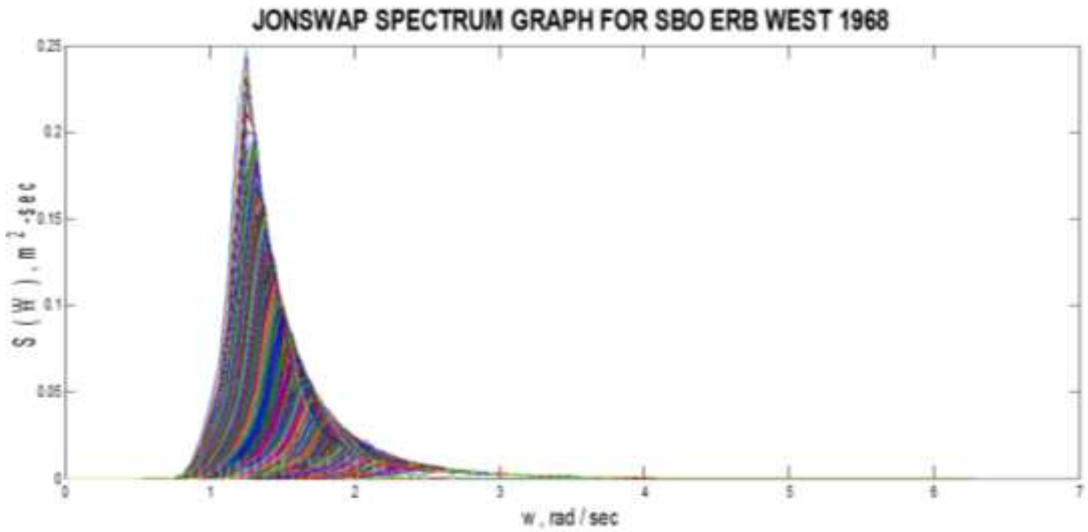
II. WAVE ENERGY SPECTRUM (PMO DULANG 1968)

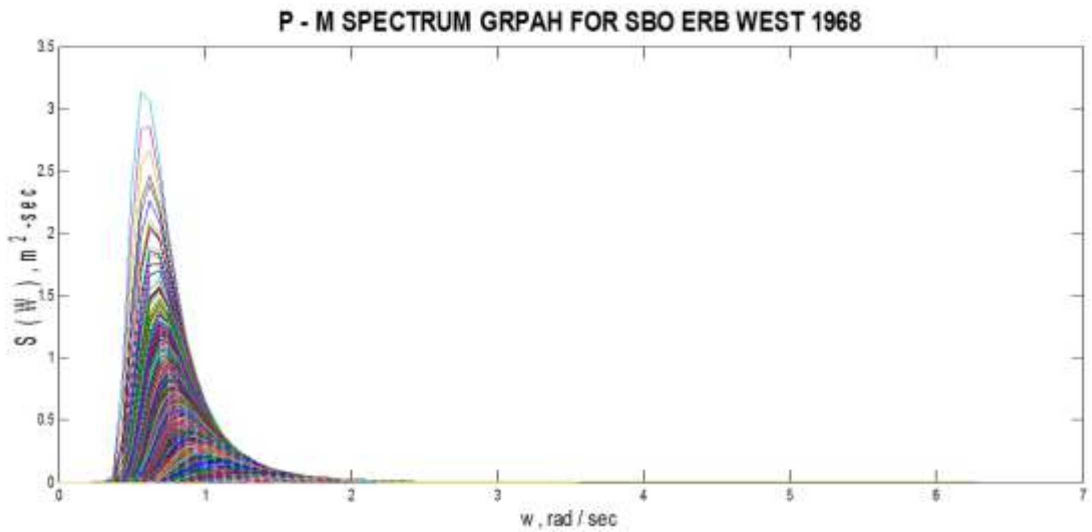


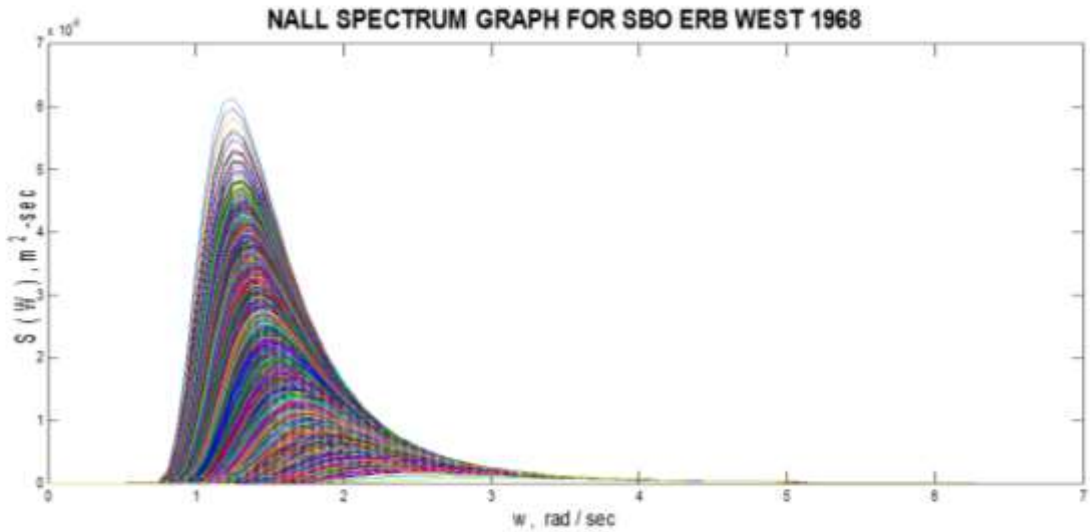




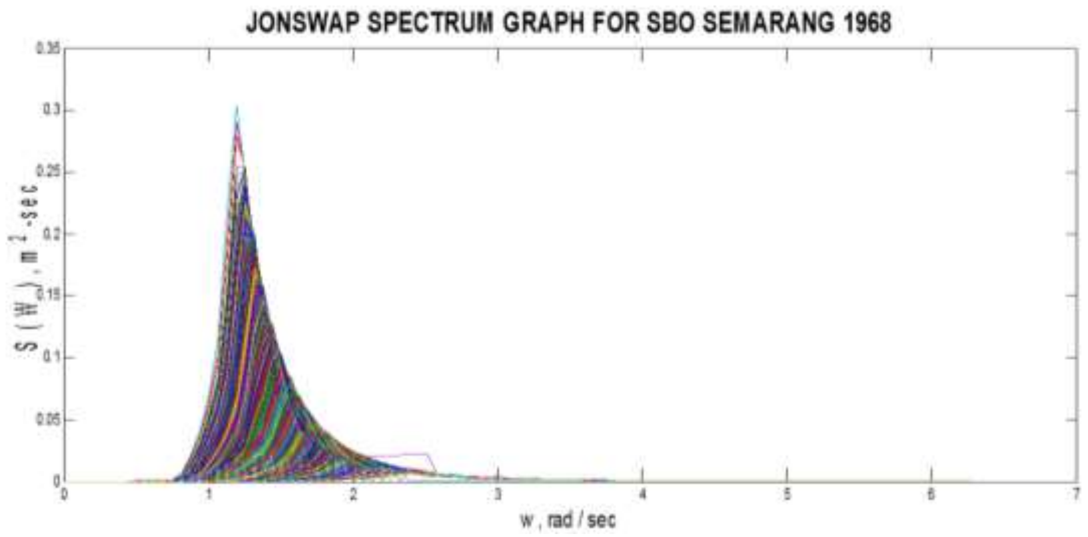
III. WAVE ENERGY SPECTRUM (SBO ERB WEST 1968)

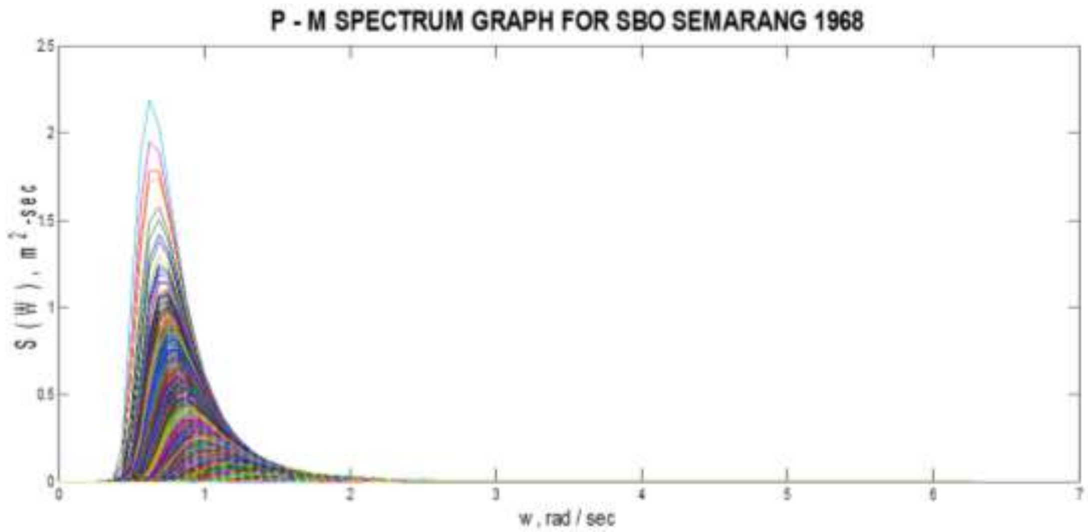


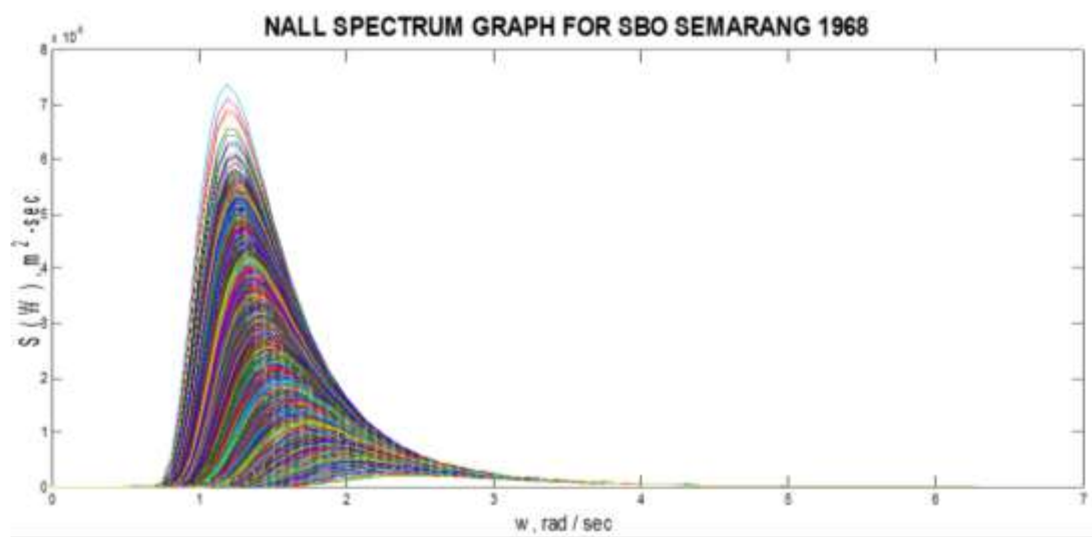




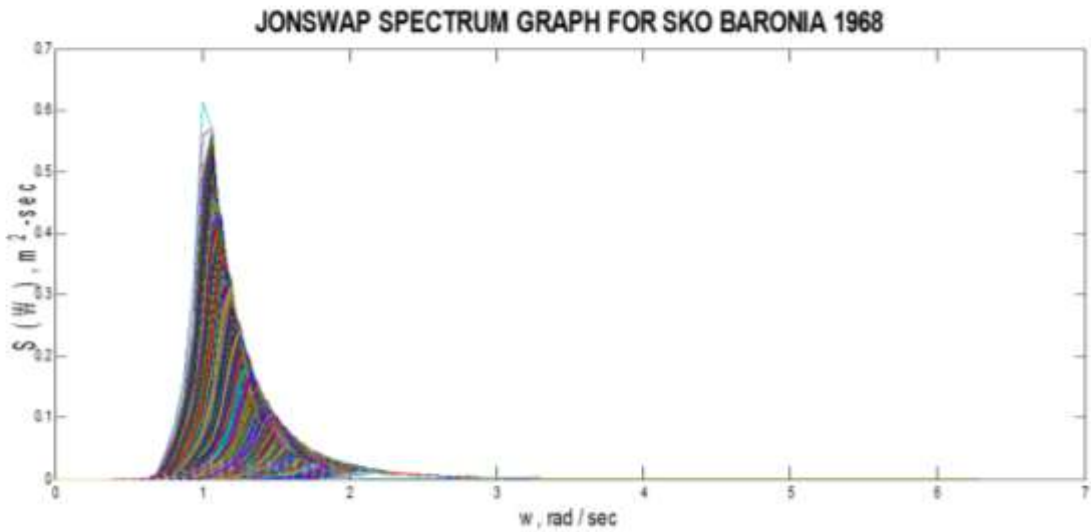
IV. WAVE ENERGY SPECTRUM (SBO SEMARANG 1968)

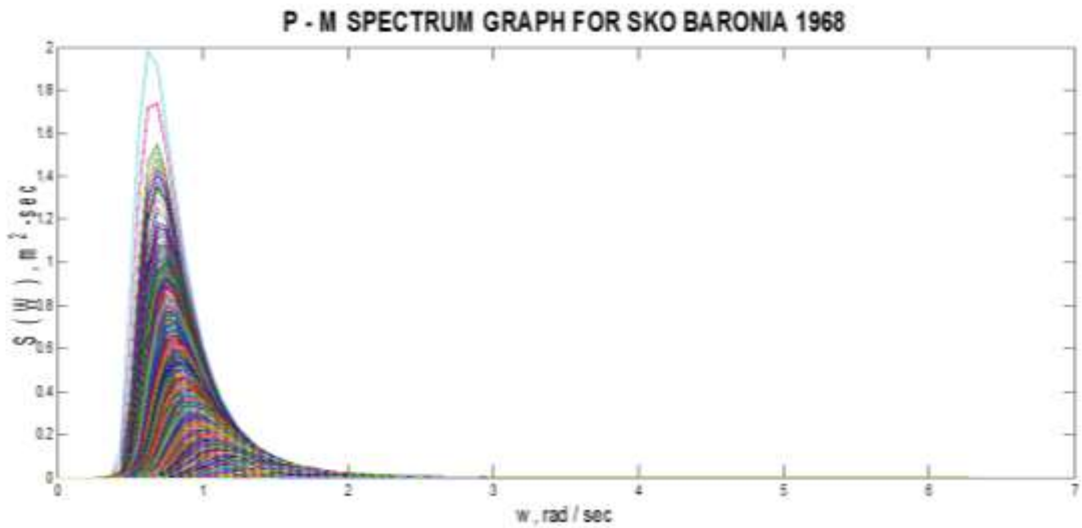


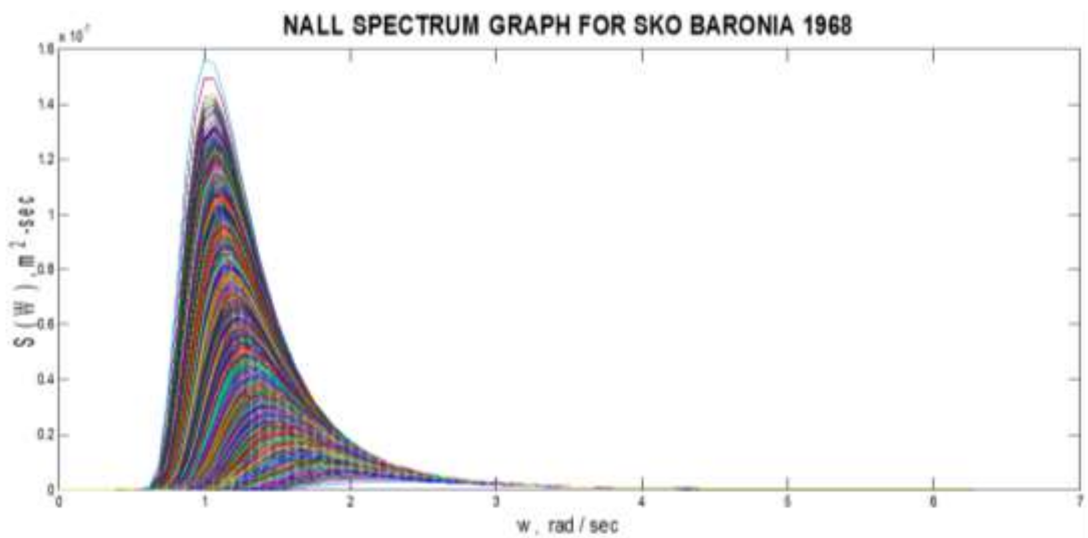




V. WAVE ENERGY SPECTRUM (SKO BARONIA 1968)







VI. WAVE ENERGY SPECTRUM (SKO TUKAU 1968